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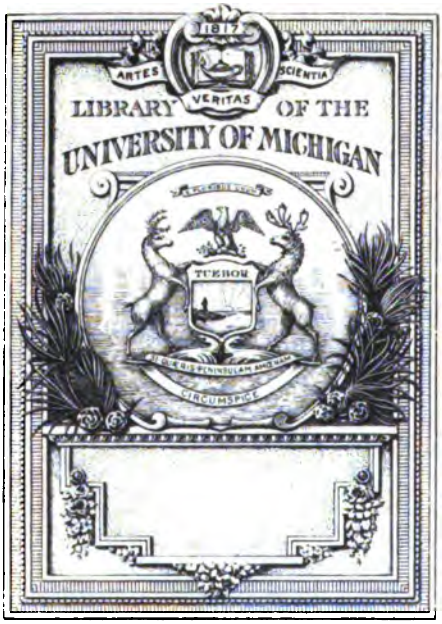

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A

VIEW OF NATURE.

VOL. I.

A
VIEW OF NATURE,
IN LETTERS
TO A TRAVELLER AMONG THE ALPS.
WITH
REFLECTIONS
ON
ATHEISTICAL PHILOSOPHY,
NOW EXEMPLIFIED IN
FRANCE.

BY RICHARD JOSEPH SULlIVAN, ESQ.
F. R. S. AND F. A. S.

> Mala enim, et impia consuetudo est contra Deos disputandi, sive ex animo id fit, sive simulate.
>
> CIÇERO.

IN SIX VOLUMES.

VOL. I.

LONDON:
PRINTED FOR T. BECKET, PALL MALL,
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THE PRINCE OF WALES,
AND THEIR ROYAL HIGHNESSES, THE DUKES OF YORK AND
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1794.

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PREFACE.

THE following Letters were begun in France, in the year 1789, and were continued from that country, from Italy, from Germany, and from England, through the years 1790 and 1791. Their principal object was, to expose the fallacy of the *atheistical* philosophy, and to shew how little support its advocates could derive, either from physics, when well understood, or from metaphysics, when cleared of extravagancy. In the prosecution of this design, the Author has been led into a wide field of observation in various branches of science: and he has often availed himself of the privilege of epistolary correspondence, to make excursions beyond what would have been admissible in a systematic work.

It has been said, that it is the indispensable duty of a Writer, either so to represent new things, as that they may appear familiar; or so to represent familiar things, as that they may appear new. The Author of the present work having few pretensions to the credit of discovery, or invention, will be satisfied if he shall be found to have placed, in an interesting light, facts and truths already well known. His aim is, merely to bring into an abridgement the scattered laws and ordinances of philosophy, and to hazard an humble commentary, wherever it appears necessary.

If, in the progress of this discussion, the Writer has been led, through the medium of physics, to ascend to higher contemplations, he has studiously avoided all scholastic subtilty; and while he has made a confident appeal to the understanding of his readers, he has endeavoured, with no small degree of solicitude, to engage their generous affections as advocates on the side of religion.

That the purpose of these Letters might not be defeated through any want of ability in the Writer, and that his argument might not suffer through any deficiency of materials, recourse has been had to every authority which has come within his reach: for, science being only a continual accumulation of knowledge from the contributions of individuals, the Author has consulted Writers of all classes with diligence, and he is willing to hope, without prejudice or partiality. He has freely borrowed where it was necessary; and, in short, has taken every step that was in his power to come at truth. It will, he trusts, be seen, that he has forborne the assumption of any credit, which in any respect appertained to another. Even in language, he has been so far from wishing to dress up that which he has borrowed from others in newer or more appropriate terms—that he has almost uniformly adhered to his text. Various expressions, and even whole sentences, especially upon elementary principles, he has given in the very words of the writer from whom they have been selected. It has been, in a word, his anxious desire, to present his ideas and sentiments to the reader in such a garb, as would at once render them most striking, and most perspicuous.

With the best and fairest intentions, however, we are too apt to fall into errors and mistakes, while we are engaged in the eager pursuit of a favourite object. Should, therefore, the Author have inadvertently failed to quote, or neglected the opinion of any enlightened philosopher, in whose footsteps he has with reverence endeavoured to tread, he has unaffectedly to solicit the indulgence of the reader for that, which he muſt conſider as a loſs and a miſfortune peculiarly applicable to himſelf. For accidental omiſſions of particular references, the candid reader will think a general apology ſufficient.

In fine, as the purpoſe of the following pages, is not to intrude upon the learned an unneceſſary repetition of what they already know, but to point out the paths of knowledge to the leſs instructed, and to excite an attention to objects in which all men are equally, and in the higheſt degree, intereſted; it is hoped, that an attempt in ſo wide a field, and in ſo good a cauſe, ſhould it not be entitled to approbation, will, however, be received with candour.

The reader is requested to correct the typographical and other errors, which are noticed in the *errata*, and which were occasioned by the Author's being frequently unable to attend to the revision of the Press.

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LETTERS

TO A

TRAVELLER

AMONG THE ALPS.

LETTER I.

I REJOICE that you are at length returned from your tour into Italy, and that you have once again taken up your abode in the beautiful and truly philosophic region of Geneva. It is a wise measure. It is placing your time at a profitable interest. Health and fortune were yours before. Nothing was wanting to fill up the measure of your riches, but that you should fix upon the spot, where you could with facility obtain the means of acquiring that knowledge, which you are so eagerly pursuing, and which, if your perseverance be proportioned to your zeal, you will not fail to attain.

You need not be told, that to a wise man, who possesses a determined spirit of industry, scarcely any thing in the whole circle of human knowledge will appear unattainable. Application is all that is necessary; but that, I fear, is much more frequently wanting than ability. We do not in general feel it ourselves; but, idleness is the infirmity to which, above all others, we are most apt to yield without resistance. Is there a pursuit in which we engage, which does not at first cost us a struggle with this secret foe? How few, in truth, are the instances in which it does not subdue our best resolutions! This inert tranquility of spirit, when indulged, becomes a malignant supineness, which lulls and cheats us into sluggish procrastination. In every instance in which it gains the ascendancy, it entails upon us an irreparable loss. In a word, it fetters those powers which were given to man for better purposes; and, as his evil genius, would substitute itself in the place of every possible kind of good. "Nous avons plus de paresse dans l'esprit que dans le corps," said a French philosopher—and he said justly.

In the country, where you are now about to recommence your amusements and your studies, I need not inform you, that you will find, not only a concentrated, and an unique aggregation of almost all the wonders of the natural world, but an industry and an urbanity, which render all those singular advantages not only pleasing, but of positive and universal utility to mankind. Would you seek for the awful and the enchanting, where is the spot in which they more profusely abound? Should less sublime, though perhaps more instructive objects, rather attract your attention, where are there governments of more liberty—people of more chearfulness—or happiness and plenty more equably diffused? Switzerland, for here I must include the whole compass of the Helvetic chain, is a most captivating spot! No man of honest feelings can see it, without glowing emotions of admiration and delight. Genius, for ages, has established herself in this favourite spot. Philosophy and liberty seem indigenous to the soil.

LETTER II.

IT is a serious, and I am not certain whether it may not be a dangerous sort of compact, into which I have entered. To endeavour to satisfy all the perplexing doubts of a young and a vigorous mind, is a task of no small difficulty. Besides, the lists are not fairly arranged between us. You decline the defensive part of the combat, and with all the caution of a wily practitioner, propose to confine yourself to forcible and merciless attacks. But no matter; the odds are of little consequence. You anxiously call upon me; and as it is in the province of my affection, so shall it be my delight, to engage in a contest, the issue of which may prove advantageous to you.

From the general tendency of your letters, however, I fear I have more than common reason to apprehend, that from vivacity, or from a fashionable dislike to every thing grave or serious, you have contracted an habit of thinking, which may plunge you into error. As to any effect so latitudinarian a bias may have upon your moral conduct, on that head I am determinately at ease. The sterling integrity of your heart is not to be debased by any, though the most sceptical, alloy. All that concerns me is the possibility, that this humour may rivet prejudices, and eventually deprive you of any disposition towards fair investigation and enquiry. You have now traversed many countries. Three years constant residence alone on the continent must have given you an insight into men and things, much beyond that which has been the lot of others. But, with this advantage, for it is certainly an advantage to be allowed time to disperse the too frequent illusion of first impressions, I think I can perceive something like an inconsiderate propensity to turn matters of weighty import into ridicule.

Among the nations, with whom you have lately passed your time, it is certain, the mind adventures farther than in others less oppressed by the hard yoke of clerical usurpation: and the reason is obvious. In a country, where a man has liberty to think, it is not unfrequent, indeed, to meet with persons who reject revelation; but, in soils which have been nourished by sanguinary superstition, atheism has, I fear, always had the most luxuriant growth. Religion, seconded and enforced by an intolerant sovereign authority, through the impolitic abuse of its arrogated power, bends the soul into a sullen and discontented subjection. Powerfully, however, though silently irritated by so galling a chain, the collision of discordant sentiments at length strikes out a flame of impetuous force. The God which serves as the prop of a debasing system, finally becomes as odious as the system itself. Oppression gives a dreadful energy to the mental powers. For a time, indeed, this may be stifled; or it may at least be concealed from the watchful eye of the jealous tribunal. But where is the understanding, which in an enlightened age can rest its hope and belief on a terrible, a cruel, and revengeful Deity?

As one extreme begets another, atheism may then fairly be considered as the natural production of superstition and enthusiasm. Each is a distinct species of lunacy. The religious enthusiast, grave and severe, believing every thing, and groaning and sighing from the very principles of his belief, long broods over his fanatical conceptions. The paroxysm of bigotted phrenzy at length turns his brain; he then, most deeply and perniciously insane, premeditates mischief. As a spiritual Quixote, he grows enamoured of visionary absurdities. He searches about for opponents to his doctrine: he traverses the whole circle of human imbecility and distraction: he bruises, lacerates, and famishes his own unfortunate frame; and as a consistent termination of the delirium, and actuated as he thinks by the true spirit of God, he burns and destroys all others of his fellow creatures, who are so blasphemous as to differ from him in opinion.

When all these horrors, with an endless catalogue of attendant evils, are seen to originate from implicit faith, it is, I fear, most natural for the human mind to set up a new idol of its own.

Gaiety and pleasure, says the voluptuary, are more befitting man, than weeping and gnashing of teeth. Let this wretch groan and sigh for religion and its mysteries; to me they are indifferent and of no concern. The way of truth is plain; and I want not a priest to point it out to me. The votary of religion is the blind instrument, which craft uses to establish imposition on the world. Thus they both of them rave, and deviate from the rules of common sense. The one is gloomy and ferociously distracted; the other is merrily, but perhaps not less franticly mad.

You will pardon me, I am sure, for this serious kind of exordium. I mean it not as an impertinent obtrusion on your own good sense. It flows from me merely as a general point, preparatory to the reasoning, which I shall endeavour to establish on broader grounds, in the subsequent part of our correspondence. Voltaire, Mirabeau, Helvetius, and many others, whose works you have evidently studied, have fatally decked the plains of libertinism with bewitching and fascinating flowers. Wit, brilliancy, and in many instances, strong argument, these writers certainly possessed: but they should not be looked upon as infallible. When they set themselves up as dictators, it should be remembered, that their keenest shafts have been levelled at the structures which have been reared on the belief of the being and attributes of God. This, if nothing else, should put us upon our guard. Pleasantry and merriment are little suited to momentous and sublime speculations.

In one of your last letters, you tell me, the system of atheism is the natural fruit of much and continued study, in a mind cooled by reason and by experience. The quiet Epicurus, you say, never troubled Greece. The poem of Lucretius did not cause the civil wars at Rome.

Bodin was not the author of the League. The writings of Spinoza excited not in Holland troubles, like those which were occasioned by the disputes of Gomar and Arminius. Hobbes did not cause blood to flow in England, when at the very moment religious fanaticism brought a king to the scaffold. And you conclude your enumeration in these remarkable words, "Atheism leaves men reason, philosophy, natural piety, laws, reputation, and all that can serve as a guide to virtue; but superstition destroys them all. Atheism never troubles a state, but, it makes a man more provident for himself, seeing, as he does, nothing beyond the limits of this life."

In reply to this, I shall for the present be brief. I shall leave to a future opportunity the consideration of this seducing but erroneous principle. An unqualified reprobation is all that I shall now bestow upon it; and that too merely from the horror I feel, at the thought of emancipating frail beings from the obligation of answering to their Maker for their conduct, and at the apprehension of their reducing, as has been expressively said, all their affections to a secret egotism, as prejudicial to virtue as to liberality. Whether there be, or there be not another life, the belief of it cannot be injurious to man, either now or hereafter. To console ourselves with the hope of it, is at least to do honour to human nature. It cannot be looked upon as a faulty weakness, to believe that to be probable, for which probable reasons may be assigned, and when it is our highest interest that it should be true. If I am to be mistaken, let me be mistaken in the adoption of an opinion, which has for its object the good of mankind. "Id primum ita esse velim; deinde, etiamsi non sit, mihi persuaderi tamen velim." *

It is said, that the most religious men are in general the most inflexible misanthropes; that they are useless to the world, and injurious to themselves. I will grant it—but with this exception, that it be really confined to a bigotted and unenlightened order of religious men. Among these, indeed, energy of mind is often manifested in voluntary mortification and suffering. Barbarous and slow self destruction is celebrated as the acmé of great and sublime piety. In a word, they chaunt forth their God as a being of goodness and mercy, and yet aim at the acquisition of his favour, as if he were a demon of insatiable ferocity. I will farther acknowledge, it is

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* Cic. Tusc. Disp.

is not necessary to commit homicide on one's self, in order to be virtuous. Real merit, or virtue, depends on a proper knowledge of justice and on a firmness of reason, capable of directing us in the managament of our affections. He who, tired of the struggles of this life, finishes the quarrel by a pistol, is called a mad-man; but, he who, staggered by such brief procedure, takes daily, for the love of God, a dose of poison, which slowly but infallibly conducts him to the tomb, is he less a fool than the former? If suicide be a crime, what matters it whether a man kill himself by fasting and praying, or by sublimate or arsenic? In an instant, or in a dozen years? This is but a dispute on the manner, and not on the crime itself.

He who shuns the world for the sake of religion, assuredly draws from the common stock of humanity that which he owes to it. "Come, holy recluse," says the philosopher,* "suspend for a moment the intenseness of your meditations, and deign to be undeceived by a man of the world. I have passions, and I should be sorry to be without them. Most fervently do I love my God, my king, my country, my parents, my friends, my wife, my children, and myself. I look upon riches with satisfaction. I have store by me, and yet I should not be displeased with more. For can a man who wishes to do good be in possession of too much? What delight does it give a good man to animate those talents, which he sees languishing in obscurity! What joy, to unite that pair whom indigence alone keeps separate! It is true, I meet with ingratitude. What then? My heart warms towards my fellow creatures. Pleasures that are innocent I love. I quit them as seldom as I can. From the table, less sumptuous than delicate, I go to the opera, or to the play. I guard myself with all my might from gloomy reflections. Hope and tranquility, inseparable companions of honesty, conduct me by the hand, through flowery meads, towards that bourne whence no traveller returns. And think you, your end will be more tranquil or comfortable than mine? Conscience will not then trouble me; for at the worst, I have not been unuseful to my country, my family, or my friends."

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* Philosophie Morale.

This wordly yet rational address to the miserable Frere de la Trappe, or the Chartreux, is not assuredly overcharged. It is nothing but common sense, dictated by sane and common feelings. But it is too frequently the [illegible]tched lot of men, to take less pains to make themselves happy, than to be thought so. This we have both of us, in a thousand instances, seen exemplified. In arguing, if you recollect, with very respectable though too rigidly professional men of the Catholic Church, not only in Italy but in France, on this subject, we uniformly found them inflexibly tenacious in their opinion, That though we have all the same God, the same beginning, the same wants, and the same end, yet that man was evidently born to be a stranger to man; and that the less we acted as men in this state of existence, the more we should be rewarded as select objects of divine favour in another.

LETTER III.

THERE is no weakness more common, nor any one more illiberal, than that of an indiscriminate sneer at religious institutions. How few are there of us, who previously consider the relative and political situations of the countries in which such religions are established! Proud of a self-assumed authority to judge, we venture upon a superficial glance, to condemn all professions and all professors. But, can there be any thing more ungenerous or unjust? Can there, let me ask, be any system of faith or of practice so totally defective, as to be in all its parts deserving of contempt? Or, however contrary to our own way of thinking, can there be any body of spiritual teachers, who merit nothing but ridicule and censure?

Besides their unbounded claims to temporal as well as spiritual dominion, and their abject and comfortless austerities, many puerile subtleties, it must be confessed, have disgraced the character of certain orders of the priesthood. In attempting to illustrate their principles, they have, in many instances, extinguished the very spirit of their religion. They have thought it necessary to employ the aid of science in propping up a sacred edifice, confessedly raised by God himself. In a word, learned pride, with inflated tyranny and arrogance, have been substituted in the place of Christian humility and forbearance; and the sublime simplicity of their master's laws, has been lost in scholastic refinement.

Notwithstanding this, as the religion of every country makes a great part in its political fabric, it is neither candid nor dignified to run into the fashionable practice of exposing the profession, the persons, and the characters of priests.— Throughout Europe, the generality of the clergy lead virtuous and pious lives; at least, few of them are notoriously vicious. In their education, they necessarily become instructed in various branches of knowledge. As to their calling, surely it is not a contemptible one. The subject of it is God and truth; and the end at which it aims is the peace and the happiness of mankind. But, not to confine ourselves to the present moment, or to Christian ground, cast a retrospect on the mythologically hallowed soil on which you have recently been travelling. From the commencement to nearly the conclusion of the Roman empire, the king was always priest or pontifex. Æneas, says tradition, was *sacrorum rex*, or pontifex. Julius Cæsar by election became high priest; so did Augustus; and the emperors were so of course, in consequence of their office; Gratian being the first, even of the Christian emperors, who refused the title of Pontifex Maximus. And hence, as it has been remarked, it is well for free-thinkers, classical ones in particular, they live in times when liberty is so well understood as it is at this day among us; for had they lived in the boasted days of Pagan freedom, he among them had been fortunate, who should have escaped a character, esteemed by their favourite ancients the most infamous of all, that of an enemy to the religion of his country.

As a brilliant elucidation, let me intreat you to cast your eyes on the enlightened and truly respectable Clergy, by whom you are at present surrounded. They afford a delightful spectacle, and lead to a veneration of the system which can produce such benevolent and such able pastors. Nor let predilection for the reformed church be supposed to actuate me to this opinion. Hear what a Roman Catholic says, not only of the Clergy, but of the whole Helvetic nation. Treating of the dreadful carnage and destruction caused by the difference of opinions in religion at a memorable æra, the Author of *L'Esprit de la Ligue* has these words:—" Les Suisses furent peut-être les seuls qui s'armerent par un vrai zele depouillé de tout motif humain. La Doctrine Catholique et celle de Zuingle eurent leurs bornes assignées; et les efforts qu'elles ont faits reciproquement dans la suite pour les passer, ont toujours été réprimés sans guerres civiles." Such then being the case, when intolerance had reared its monstrous head almost universally, what must not their character be now, when among nations of the purest religious liberality, they still hold a conspicuous and eminent situation?

It is an erroneous opinion, that sequestration from the world, and a total dereliction of all pleasures and all business, are essential to the full and powerful exertion of our mental faculties. The man who has received from nature a sound and discriminating judgment, and who, as a stock of materials on which to exercise his faculties, has acquired a fund of useful knowledge, cannot be deprived of his ability and inclination for study, by any active pursuits for the benefit of society, or by any lassitude or fatigue from public employments. An ardent and a versatile mind will find moments for study and for amusement, as well as for business. Trying its force on variety, its keenness and assiduity will increase. Pleasure springs from the source of unfettered scientific investigation; and stability of strength from the exertion of our faculties. Men of feeble parts, I confess, are not to be included in this number. I speak of those select and exalted minds, "quos ardens evexit ad æthera virtus." But, retirement is far from being indispensably requisite. Cicero, Xenophon, Cæsar, Bacon, De Thou, and a variety of others, not only did more, but thought more, and wrote more, than any mistaken recluse that ever existed. But, thrift, and frugality in the disposition of time, are points which are in that case absolutely necessary. Careful and undissipated in the application of them, a man's hoard will so rapidly increase, that in the end, he will have accumulated a stock, not only adequate to every common demand, but amply sufficient for every future contingency.

We sometimes, however, meet with a man who drones away his existence; and who, even in the bustle of the world, is as thoroughly interred, as though he were irrevocably fated to a residence six feet under-ground; who is still, if possible, more to be commiserated than he who devotes himself to the austerities and penance of a cell. Such a living dead man is a wretched being. He neither has intellectual satisfactions, which forcibly give birth to the social affections; nor has he even imaginary plans, to sooth him with the prospect of eventual retribution or reward. Such an animated nothing is pestiferous. The contagion of his baneful apathies has an enfeebling and unhinging power, like that of the Sirocco wind, so fatal to animal vigour in the south of Italy. No blow which active virtue can receive, can destroy her native energy. Storms and tempests may howl around, she is still herself: in the midst of every gloom, she is still irradiated by her own native splendor. The warm and properly tempered affections are in every instance the soothers of melancholy, the counter poises to ill-humour, and I had almost said, the panacea for bodily disease.

LETTER IV.

IN the full persuasion, that a little cool reflection on the subject of our late correspondence might have diverted you from the unfavourable impression you had imbibed, not only relative to priests, but even to religion itself, I had formed the resolution to have given up the discussion. But, you press me to be more explicit. You frankly confess the present bias of your mind; though, at the same time, you candidly acknowledge it to be open to conviction. I am delighted with this ingenuousness, and I will repay it, if it lie within the compass of my abilities.

For the present, however, I shall wave any close investigation of the principles, which, I had supposed, might have been sufficient for, at least, your general conviction. The ignorant, the unexperienced, and consequently the superstitious man, we will leave in his cell. There, let the winds whistle round him; the lightnings dart, and the thunder roar: bent down with terror and apprehension, he will shrink into himself; and mumbling over his prayers, will tremblingly, and without a friend or child to cherish him, repose upon abstract spe culations, and incomprehensible mysteries. Neither will we dwell any longer upon moral rectitude, and that which is supposed, if not by every one acknowledged to be, unequivocal human happiness. Pleasure, riches, power, we will leave to those who search after them, and the number is not inconsiderable. The felicity of life must speak for itself. How the case really stands, every one will insist upon being the best judge himself. This, however, I think is clear, that good, in fair comparison, would be found equal, if not paramount to evil, were we as accurately to sum up the number of blessings, as we are rigidly severe in the enumeration of afflictions. How few are there, who balance the eagerness of hope by the calmness of resignation; the inclination to pleasure by the dictates of discretion! Our disappointments too frequently originate with ourselves. In our expectations we are immoderate; in our estimates, seldom impartial.

At this moment, however, and before we engage in either physical or metaphysical speculations, let me suppose you, for an instant, divested of all immediate and relative considerations of self. Stripping the subject we are to discuss of all delusion and imposition, let me imagine you surveying the universe; and to the utmost extent of your finite ideas, endeavouring to trace a link of that infinite chain which binds the universe together. In this survey, how much more elevated and edifying should we find it, to attempt a sketch of the history of the globe itself, than to mark the petty revolutions of its inhabitants. Though of undoubted consequence to those involved in the struggle, yet of what moment is it to us in our emancipated flight, to know, that in certain divisions of the earth, certain sovereigns have held the supreme command, and that there they fought and extirpated half the race of man? Such affairs as these have ever been looked upon as the little under-plots in the tragi-comedy of the world. But the rise and fall, the various revolutions of an entire and habitable globe; how God hath varied nature, and hath benignly adapted to a material form an intellectual mind—these are sublime contemplations; they lead us to a faint and distant view of his providence, and amply, in the result, repay us for the investigation.

The great Roman orator, whose eager researches were neither restrained by time, nor bounded by space, contemplating the natural state of this earth, bewildered himself in the wily maze of the inextricable labyrinth, nor knew where he was to fix, nor how he was to establish even conjectural hypothesis. Hence Sulpicius also, on his return from Asia, and having in the course of his voyage seen Ægina, Megara, the Piræeus, and Corinth in ruins, expresses himself to Cicero, " And shall we, short-lived creatures as we are, bear with impatience the death of our fellows, when, in one single view, we behold the carcasses of so many lately flourishing cities?"— Thus, if common dilapidations, such as these, are capable of impressing the soul with awe, in what temper of mind are we to reflect on the ruins and disasters of a world? Mont Blanc, which now so tremendously rises above you, was once covered by the sea. The very highest point of the present earth was once a part of the bed on which the waters rested. How grand, how sublime the idea!

These are the objects, which it is delightful, which it is instructive to dwell upon. The mountains of the earth, the caverns of the ocean, the host of the innumerable globes that roll through the regions where the stars inhabit; these are lofty and most worthy speculations. From the things, we pass to the Maker, and we glorify God and his greatness. In admiration and incomprehensibility we are indeed lost; but, we are supported by enthusiasm and by gratitude. The excess may be overbearing, but the immediate, if not the ultimate joy, is infinite.

As the first and the preparatory measure, therefore, let us in imagination rend from this earth its cities, its towns, and its inhabitants. As one bold and inartificial whole, unstocked with animation, let us contemplate its shape, its nature, and its parts: undressed, uncultivated, and unadorned, teeming with various blessings, but still attended with supposed imperfections, let it pass before us in calm and unprejudiced review. The mist of error which too frequently distorts our vision, when we are ourselves as principals concerned, will thus be removed; and we shall, in our speculations, follow the guidance of nature and reason, without being disturbed by those storms of passion, by which human reason is tossed to and fro in the vast ocean of opinion.

LETTER V.

IN the line which I shall lay down, for our future investigations, (for I must still request your permission to postpone them for a short time) I shall endeavour to the utmost of my power, to avoid that extravagant delirium, which too frequently impels men to the creation of visionary systems. Such flimsy fabrics of fancy are too often substituted in the room of plain realities. An attempt to disperse them, is to the irritable mind of their respective builders, as much an object of dread, as if they were not the illusory offspring of the imagination. By us, however, a different path must be pursued. We shall rarely touch upon any thing, but that which we can see; nor shall we in any instance, I hope, be detected in endeavouring to be thought to see more, than that which has a real existence.

It is a truth, however humiliating it may appear, that with all our knowledge, we are in most unequivocal darkness. With infinite facility we make worlds; we even compose and string together whole planetary systems; but yet can we say how the common surface of the earth was formed, or how it was furnished with fruits, with pulse, and with that vast variety of nutritious aliment, so providentially supplied for the support of animal life? Can the deepest of our philosophers determine, whether plants were created in their seed, and so dispersed through the elements which had energy to push them into being; or whether they were planted in their pristine soils in the fulness of beauty and maturity? Of the most familiar objects we are in total ignorance. Why then do we idly and presumptuously venture beyond our line? The mind that rushes beyond what experience, or what common sense renders comprehensible, is most indisputably deranged, if not actually insane.

Notwithstanding this impenetrable barrier between the creature and the Creator, proud man, full of arrogance and weakness, and in no one instance more conspicuously so, ventures, within the narrow boundaries of his closet, to explain and account for the mighty fabric of the universe, how it was drawn together, and even what it was at its origin. Thus do philosophers wander in the mazes of error. The compass traces out the geometrician's world; salts fly to the chymist's aid; and to the mineralogist, fire and its raging properties. Each, in a word, interprets the operations of nature, agreeably to the art with which he is the best acquainted.

In adverting to circumstances of this nature, the celebrated Boerhaave, not many years ago, conceived it to be useful to lay down certain pre-established data, in palpable and flat contradiction to the opinions at that time fashionable, of destructions, regenerations, and transmutations. He levelled indeed his doctrines chiefly against the alchymists. But, as what he then said, must invariably continue to hold good, I shall give you an idea of it, and, as nearly as possible in his own words. First, he alleges that there are several elementary bodies of such simplicity, that no person can either separate or assign the principles of them. Secondly, That besides the four elements which are known, salt is of the same simplicity, and does not vary otherwise than by its associations with other natures. Thirdly, That metals, quicksilver included, are all of an equal simplicity, entirely different among themselves, and absolutely different from all the other natural bodies. Fourthly, That pretending to form a metal, with a matter that has nothing metallic in it, by a transmutation of parts, is being as far from truth, as earth from heaven. Fifthly, That such as these bodies are in a large bulk, such they are found again in the smallest parcel. Sixthly, That all impulsions and attractions may blend, and mingle the elementary natures together, vary them by these mixtures, amalgamate, divide, and make them fine so as not to be perceptible; but that all simple natures remain indestructible, and unshaken by any action whatsoever of what is created. Whence it follows, that even chymistry, which employs natural agents, cannot go farther than the force of these agents will admit, and is confined to the uniting or disjoining of natures already made; but can neither destroy what exists, nor change it into what it is not, nor produce a single grain of a new nature. "Chemia adunat vel separat, nec datur tertium facere quod possit." And hence, continues Boerhaave, Newton was mistaken, in thinking that earth could be changed into fire, and Boyle equally so, in supposing it could be changed into water, or that water could be changed into earth.

Physics and mathematics are certainly of infinite value, but they have been extravagantly misapplied. In their genuine light they are to be considered, the one as relative to causes, and the other as relative to effects. But from this they have been diverted, however clear it is to sober reason, that the causes of nature are not to be discovered, either by chymistry or by mathematics, though it be possible for some of her effects to be ascertained by them. Sensible of this, the immortal Newton, who was privileged, if ever man was, to grasp at an unlimited idea, most cautiously guarded himself in the use and application of even the mathematics. Effects were all he presumed to ascertain. He openly confessed his ignorance of causes. In no one instance is it to be traced, that this wonderful man stepped beyond the boundaries of nature. His expression generally was, "All things considered, it thus seems probable to me." Indeed a contrary conduct, of which he has been erroneously accused, would have been as ridiculous in him, as if he had undertaken to shew how fire burns by algebra; to explain the nature and operation of the sun by trigonometry; or to assign the causes of vegetation by the theory of conic sections. The same inherent modesty, likewise in one, who in some respects may be considered as his master, manifested itself in Epicurus; nor was it one of the least instances of that philosopher's wisdom, that he made it one of his first physiological doctrines, that he had nothing to do with *τα δυνατα και τα ενδεχομενα*, "Matters merely possible, and merely contingent;" and therefore it was his custom to conclude all questions about the phænomena of the heavens, and all other remote and uncertain enquiries, with these words, "It may be so."

But you will ask me, if all hypotheses in physics are to be banished? So strict a limitation would, I must confess, be in the opposite extreme. For though hypotheses are not sufficient either to explain the mechanism of the world, or to demonstrate the first principles of things, they are not without their advantages. In various matters we have been greatly indebted to them. But we should be guarded in their use: to penetrate into an abstruse point, and to throw a ray of light upon it, is certainly, if nothing better, a powerful stimulant to others, to employ their invention and ability, and to render in the end, perhaps, that evident and clear, which would have otherwise been impervious. Many things likewise, whose figures are not visible to us, we must admit upon supposition; wherefore, if the hypothesis be but adequate to the phænomena, I acknowledge we should admit it; and in this concession I apprehend we have granted as much as philosophers ought to do, and as much as should be prescribed to human ingenuity. From the errors even of wise men, wisdom is to be gathered. All that is to be avoided, is too much pertinacity in the support of systematical conjecture.

LETTER VI.

THE amazing intellect, which enables us not only to perceive objects, but to contemplate them; to compare, to unite, and to disjoin them in a thousand different ways; whose unbounded activity, not only acquires the knowledge of things, but transports us into futurity; recalls past ages; collects into one view all the pleasures of life; extends our existence beyond the grave, and triumphs over death itself; is yet, in its essence, as incomprehensible to us, as is the divinity whence it derives its power. It is with its operations alone that we are acquainted. But, of this, more hereafter; we must not anticipate. We will now endeavour to collect the scattered rays of some natural phænomena, and drawing them into one powerful focus, concentrate them into a point, I will hope luminous, if not convincing.

Familiar as you are now become with the Alps, it yet may not be amiss to recall to your mind the moment when you first beheld that awful and majestic aggregate of mountains, whose hoary summits prop, as it were, the heavens. How sublime the sensations occasioned by the grand assemblage! How astonishing to one who for the first time visits the mountainous parts of the earth; who never had reflected upon their structure, nor ever had dared to form an idea of the power in nature, which could be sufficient to produce them! Do you recollect the wonder with which you viewed the Shriek Horn, the Glaciers of Grindelwald, the icy plains of Chamounis, and the tremendous and venerable brow of Mont Blanc? What abundant matter for surprize! How striking the profundity of the abysses! the frightful elevation of the rocks! the eternal snows! the pillars and seas of indurated water, whose existence challenges an age almost as venerable as the vales in which they are lodged! the cascades, the lakes, the rivers bursting from their source! the roaring winds! the accumulated thunder!—all these are full of grandeur, all are stamped with the character of sublimity, and speak with energy to the soul.

From these very Alps, however, the first clear ideas were drawn of the probable formation of the earth. These, together with the Apennines, the Cordeliers, the Caucasus, the Imaus, and the other vast mountains of the globe, were found to be not only intrinsically the same, but to occupy at least one tenth part of the dry land. Thus, says Burnet, our mountains are not to be supposed to have been laid upon the earth, as tomb-stones upon a grave, or to stand as statues do upon pedestals. They are one continued substance with the body of the earth. And hence it is ridiculous to imagine the earth first a plain surface, then all the mountains set upon it, as haycocks in a field: it is all one frame or mass, broken and disjointed in its parts.

No sooner had the mind begun to meddle with this mighty subject, than theories upon theories arose. Each naturalist endeavoured to get a step beyond his predecessor. The surface, the interior parts, the mountains, the vallies—all were ransacked. Nothing was left untried, that could yield satisfaction in the enquiry. But all in vain; the truth, though many important points became established, still eluded the search and the labours of philosophy. It would fatigue you much, and be perhaps little worthy of your attention, were I to detail the variety of opinions on this intricate subject. The leading features, however, of the more brilliant hypotheses may not be unamusing. And Burnet shall take the lead; for no writer, before or since his publication in 1680, called *Telluris Theoria Sacra*, ever entered so sublimely upon the task, or executed it with so much beauty of imagery. He was truly the man of genius and taste. His memory was richly stored; and he wrote as if he imagined himself employed in framing the universe according to his theory.

"The earth," says Burnet, "was first a fluid heterogeneous mass. The heaviest parts descended, and formed a solid body. The waters took their station round this body, and all lighter fluids rose above the water. Thus between the coat of air and that of water, a coat of oily matter was interposed. But, as the air was then full of impurities, and contained great quantities of earthy particles, these gradually subsided upon the coat or stratum of oil, and composed a crust of earth and oil. This crust was the first habitable part of the earth. The land thus formed, was light, fat, and adapted to cherish the tenderness of the original germs. The surface of the earth was level and uniform, without mountains, seas, or other inequalities. In this state it remained about sixteen centuries; for the heat of the sun, gradually drying the crust, produced at first, superficial fissures or cracks, but in process, of time, these fissures penetrated deeper, and encreased so much in their dimensions, that at last, they entirely penetrated the crust. In an instant the whole earth split in pieces, and fell into the great abyss of waters, which it formerly surrounded. This wonderful event was the universal deluge. But all these masses of earth, in falling into the abyss, carried along with them vast quantities of air, and they dashing against each other, accumulated, and divided so irregularly, that great cavities filled with air were left between them. The waters gradually opened passages into these cavities, and in proportion as the cavities were filled with water, the surface of the earth began to discover itself in the most elevated places. At last, the waters appeared no where but in those extensive valleys, which contain the ocean. Thus our ocean is a part of the ancient abyss; the rest of it remains in the internal cavities, with which the sea has still a communication. Iſlands and rocks are the small fragments; and continents are the large masses of the ancient crust. And hence, as the rupture and fall of this crust were effected on a sudden, and in a confused manner, it is not surprizing that the surface of the present earth should be so full of mountains, gulfs, and irregularities of all sorts."

A few years after the publication of this elegant romance, that is, in 1696, Whiston, a man of uncommon parts, and more uncommon learning, but, as his biographers acknowledge, of a still more singular and extraordinary character, published a new theory of the earth, from its original to the consummation of all things; wherein the creation of the world in six days, the universal deluge, and the general conflagration, as laid down in the holy scriptures, were shewn to be perfectly agreeable to reason and philosophy. This book met with admirers; and among others, with the approbation of the sagacious Locke. "I have not heard any one of my acquaintance speak of it," says Locke, "but with great commendations, as I think it deserves; and truly I think it is more to be admired, that he has laid down an hypothesis, whereby he has explained so many wonderful and before inexplicable things in the great changes of this globe, than that some of them should not easily go down with some men, when the whole was entirely new to all. He is one of that sort of writers, that I always fancy should be most esteemed and encouraged: I am always for the builders, who bring some addition to our knowledge, or at least some new things to our thoughts."

Whiston, who was so celebrated a mathematician, as to become successor to Newton in the Lucasian professorship at Cambridge, convinced that every possible event depends upon the motion and direction of the stars, endeavoured to prove, by mathematical calculation, that all the changes this earth has undergone, have been produced by the tail of a comet. The account of the creation, as given by Moses, he says, is not perfectly understood. It is not an exact or philosophical account; it is only an historical narration of the formation of the terrestrial globe. The earth, in Whiston's opinion, formerly existed in a chaotic state; and at the time mentioned by Moses only received a form, situation, and consistence, necessary for the habitation of mankind. He contended, that this chaos was the atmosphere of a comet: that the annual motion of the earth began when it received its new form, but that its diurnal motion did not commence till the fall of Adam: that the ecliptic cut the tropic of Cancer in a point precisely opposite to Paradise, which was situated on the north west frontier of Assyria: that before the deluge, the year began at the autumnal equinox, and that the orbits of the earth and planets were then perfect circles: that the deluge commenced on the 28th of November, according to the year of the Julian period 2365, or 2349 before Christ: that previous to the deluge, the solar and lunar years were the same, and consisted exactly of 360 days: that a comet descending in the plane of the ecliptic to its perihelion, on the very day that the deluge began, made a near approach to the earth: that there is great heat in the bowels of the earth, which is constantly expanding from the centre to the circumference: that the figure of the earth resembles an egg; and that the mountains are the highest parts of the globe. To the deluge he attributed the changes of the earth. The world, according to him, will be consumed by fire. Its destruction will be by means of earthquakes, thunder, and hideous meteors; the sun and moon will assume dreadful aspects; the heavens will seem to fall, and the whole earth will be in flames. But, after the fire shall have devoured every impurity of this globe, and vitrified and rendered it transparent as the purest chrystal, the saints and spirits of the blessed shall take possession of it, and there remain till the general judgment.

"In the beginning," continues Whiston, "God created the universe; but the earth was then an uninhabitable comet, and subject to such alternate extremes of heat and cold, that its matter being sometimes liquified and sometimes frozen, was in the form of a chaos, or an abyss surrounded with utter darkness: "And darkness covered the face of the deep." This chaos was the atmosphere of the comet, composed of heterogeneous materials, having its centre occupied with a globular, hot, solid nucleus of about 2000 leagues in diameter. The thick fluid around it was like the chaos of the ancients; "rudis indigestaque moles." Such was the condition of the earth when six days old. The next day, that is the first day of the creation, every material arranged itself according to its specific gravity. The heavy fluids sunk down, and left to the earthy, watery and aerial substances, the superior regions. The heat this body received from the sun may easily be supposed to last 6000 years, since the comet of 1680 would require 50,000 years before it cooled. Round the solid and burning nucleus is placed the heavy fluid, which descended first, and formed the great abyss upon which the earth floats, like a cork upon quicksilver. The great abyss is formed of two concentric circles; the interior being the heavy fluid, and the superior water, upon which last the earth is immediately formed. After the atmosphere of the comet had been freed from the solid and earthy particles, a pure air only remained, through which the rays of the sun instantly penetrated, and produced light: "Let there be light, and there was light." The vast columns or beds of which the earth is composed, being formed with so much precipitation, is the reason why they differ so much in density: the heavier sunk deeper into the abyss than the lighter, and of course, gave rise to mountains and vallies. These inequalities, before the deluge, were differently situated from what they are at present. Instead of that vast valley, which contains the ocean, many small caverns were dispersed over the globe, each of which contained a part of the waters. The mountains were then at greater distances, and formed not large chains; but the earth was a thousand times more fertile, and contained a thousand times more inhabitants; and the life of man, and of other animals, was ten times longer.

"All these effects were produced by the superior heat of the central fire, which gave birth to a greater number of plants and animals, and at the same time bestowed on them a degree of vigour that enabled them to exist long, and to multiply abundantly. But this heat had, besides, a lamentable effect: it augmented the passions, robbed man of his innocence, and diminished the sagacity of the brute creation. All creatures, except the fishes, who inhabited a colder element, felt the influence of the central heat, became vicious, and merited death. This universal death was accordingly inflicted on Wednesday the 28th of November, by a dreadful deluge, which lasted forty days and forty nights, and was occasioned by the tail of a comet meeting with the earth in returning from its perihelion. Its attraction made the water in the great abyss break the shell or crust in many places, and rush out upon the surface: "And the fountains of the abyss were opened." As soon as the earth escaped from the comet, the waters on the surface rushed down with violence by the same channels through which they had issued; and it was now that the earth, which was formerly a sphere, assumed its elliptical form."

Whiston neither doubted of the truth of the deluge, nor of the authenticity of the sacred writings: but as physics and astronomy, as has been remarked by Buffon, occupied his principal attention, he mistook passages of holy writ for accounts of physical facts, and for results of astronomical observations; and so strangely jumbled divinity with human science, that he has given birth to the most extraordinary system, which perhaps ever did, or ever will appear.

A short time before Whiston, about the year I think 1695, Woodward published essays towards a natural history of the earth and terrestrial bodies, especially minerals; and also of the sea, rivers and springs; with an account of the universal deluge, and of the effects it had upon the earth. "Woodward," says the illustrious French naturalist, "wanted to erect an immense edifice upon a foundation less firm than sand, and to construct a world with dust; for he asserts that the earth, at the time of the deluge, suffered a total dissolution: that this dissolution was effected by the waters of the great abyss; for that at the command of God the abyss suddenly opened, and diffused such an enormous quantity of water on the surface, as was sufficient to cover the tops of the highest mountains; and that God suspended the law of cohesion, which instantly reduced every solid substance into a powder. Thus Woodward added miracles to miracles; at least physical impossibilities, which accord neither with scripture, with mathematics, nor with natural philosophy. Yet his system, though ill conceived and worse arranged, seduced many by the lustre of a few striking facts; for he was better informed, than any preceding writer, of the superficial materials of which this globe is composed. These materials, says he, are all deposited in beds or strata; in many of which are shells, and other productions of the sea. These beds are all horizontal, and placed over each other, like matters transported by the waters, and deposited in the form of sediment. The materials of the different strata, he asserts, are arranged according to their specific gravities. But this assertion is not true; for we every day see solid rocks placed over clay, sand, pit coal, bitumen, and other comparatively light bodies. All the strata which compose the earth, says he, from the top of the highest mountains to the deepest mines, are placed according to their respective specific gravities; and hence, the whole must have been in a state of dissolution, and precipitated at the same time. But, at what time, let us demand with Buffon, and in what menstruum was it dissolved? In the water, says Woodward, and at the time of the deluge. But there was not water enough on the globe to produce that effect, for there is more earth than water; and the bottom of the sea itself is earth? But, says he, there was enough of water in the central parts of the earth. We reply, however, that water could not dissolve rocks and metals, especially in forty days, the time of the waters remaining on the earth. That signifies not, replies he; the event did happen. When it was asked him, how the waters of the abyss could dissolve the whole earth, and yet preserve the shells? he answered, he never asserted that the water was a dissolvent, but, from facts, it was clear the earth had been dissolved, and that the shells had been preserved. But, if it were further pressed upon him, that, supposing the laws of cohesion and gravity could have been suddenly stopped, and that the dissolution of the ancient world could have been supposed capable of explanation—still, why were the shells not dissolved? To this he was mute; he could give no answer.

LETTER VII.

NOTWITHSTANDING the glaring delusion of the theorists, whom I have already mentioned, and the positive certainty their writings gave, that it was impossible to offer demonstrative evidence on such a subject as creation, the game was still to be followed; and sportsmen to the full as eager as Burnet, Whiston, or Woodward, took the field. Among the foremost were Bourguet, Leibnitz, Steno, and Le Cat. It would be needless to take a review of each. I shall confine myself therefore to the latter.

Mons. Le Cat, who published his thoughts about the year 1744, supposes, that in the beginning, the substance whence metals, stones, earth, &c. were to be formed, were soft masses of a kind of mud. The surface of the earth, says he, was regular, without hills or vallies. The earth was a globe or regular spheroid. The sun and moon were afterwards created. The fluid, which covered the earth, became agitated by the violent motion of the flux and reflux. The mud on which this fluid rested was variously driven. This agitation encreasing, part of the mud became exposed, and it dried. Continents were thus formed. The materials of the earth, being more compact and solid, the sea continually excavated its bed. The continents, consequently, continually encreased: though they never arrived at a positive standard; for from the continual retreat of the sea, says he, and the excavation of the earth, this globe is doomed to be at last so perfectly undermined, as to produce a confluence of the sea, from hemisphere to hemisphere. The earth will become like a hollow orange, and its figure only be preserved by its shell. This shell also, being attenuated, will fail, and with it the surface of the earth will tumble in. A new chaos will take place, and there will be a general mixture of all its parts and productions. As at first, however, the earth will again revive, and thus we shall have a periodical dissolution and renovation according to that text of scripture: "The foundations of the earth shall perish: yea, all of them shall wax old like a garment; as a vesture shall God change them, and they shall be changed." Psalm. cii. In regard to the fossil shells every where discovered, Le Cat supposed they were buried in the earth prior to the deluge. First, because these shells, so co-acervated, or dispersed in several parts of the mountains, prove beyond dispute, that these mountains were posterior to the formation of the earth. Secondly, because these mountains did not rise on a sudden, but gradually, and consequently, are to be considered as accidental to our globe. Though here, indeed, Le Cat differed from his contemporary Voltaire, who very summarily gave these heaps of fossil shells to a less powerful cause. Can one doubt, says Voltaire, that pilgrims left them either by design or accident on these mountains? Nothing is more clear, "Si nous faisons réflexion à la foule innombrable de pelerins qui partoient a pied de Saint Jacques en Galice, et de toutes les provinces pour aller à Rome par le Mont-Cenis, chargés de coquilles a leurs bonnets." But, did pilgrims with shells in their bonnets, it might have been asked the philosopher of Ferney, ever traverse the Cordelliers, or the other unchristian mountains of the globe, where shells are to be found in even still greater profusion?

The system of Le Cat, as must be the fate of every system of a creation, was proved to be contrary to reason and to scripture. The moon and fishes, said his opponents, were, according to him, to have existed before the separation of the waters from the earth. But, it was the third day on which God separated the waters from the earth. The second day, he created the sun and moon. For here that unformed and primitive light, which God created on the first day, by saying, " Let there be light, and there was light," is not to be confounded with the sun and moon, they being very expressly distinguished in the sacred text. On the fifth day he created fishes of all kinds, consequently shell fishes. Hence the moon and fishes were created afterwards. The exuviæ left, were left by the second deluge. The general dissolution likewise, supposed by Le Cat, they declared to be in express terms contrary to Scripture, which says, " But the day of the Lord will come as a thief in the night; in the which, the heavens shall pass away with a great noise, and the elements shall melt with fervent heat; the earth also, and the works that are therein, shall be burned up." * " Ignis naturaliter aget antè judicium in bonos et malos, qui vivi reperientur, eos in cinerem resolvendo: sed mali illius ignis actione cruciabuntur, boni verò omnis doloris erunt excepti," says

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* 2 Peter, chap. iii. v. 5.

St. Thomas Aquinas in his supplement. They declared it even to be positively against God's covenant: "And I will establish my covenant with you; neither shall all flesh be cut off any more by the waters of a flood; neither shall there any more be a flood to destroy the earth."* Again in Ecclesiastes, "one generation passeth away, and another generation cometh; but the earth abideth for ever."

Le Cat, who was a man of strong abilities, did not sit down quietly under this scriptural condemnation. On his adversaries he retorted, that the knowledge of the Hebrews was miserably circumscribed. "Can the account of the creation of the world as delivered in Genesis," says he, "be said to be clear, and easy to be understood?" St. Jerome, in his Letter to Paulina, says, no. The 102d psalm quoted against him, he insisted was in favour of his hypothesis: even the passage in Peter he contended to be for him.

"Several interpreters of the Scriptures," says he, "are of opinion, the light of the first day was a luminous body, out of whose substance the sun and stars might afterwards have been formed.

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* Genesis, chap ix.

Now, if we suppose within the earth's vortex a heavenly body, whether luminous or not, it must inevitably have caused a flux and reflux. Hence it is probable this earth had been several times dissolved, confounded, and thrown into ruins. "In the beginning, God created the heavens and the earth;" that is, God created a shapeless mass of matter, in which were contained all the materials of the heaven and the earth. "St. Augustin," says he, "whose faith was so orthodox, avers, it was difficult, if not almost impossible to conceive, and much more to explain, what the six days of the creation were. For his own part, and after a thorough examination, the Saint could only determine the creation to have been instantaneous; "Simul omnia facta sunt." Saint Gregory Nazianzen was also of the same opinion: "When Moses informs us," says this Bishop, "that the world was created in the beginning, it merely signifies, that God created the plastic powers and forming causes, and that every thing existed on the first act of his divine will." "The Scriptures," again says St. Jerome, "do not consist in the letter, but the meaning; for were we to keep to the letter, we might broach new tenets." "Can there be thus any thing," continues Le Cat, "more formal, more express, than various texts of Scripture on the system of the world;

world; and yet are they not all erroneous? "The earth is fixed to all eternity," says Ecclesiastes. "The Lord has made the earth immoveable," says the writer of the Chronicles. "Thou Lord hath founded the earth so that it cannot be moved," says the Psalmist. "The sun rises and sets," says the Ecclesiastes. "It returns to the same point, and there it rises again; its circuit is towards the south, and it declines towards the west." Isaiah says, that "the sun went back ten degrees," and that this retrogradation prolonged the king's life. Finally, Joshua commanded the sun to suspend his course. Now, says Le Cat, what would become of all science, if the most positive literal text of the Old Testament, or the most explicit determination of the fathers, were to be the standards of natural philosophy? The earth, according to the Scriptures, is flat, square, and supported by the waters. St. Basil, and St. Ambrose, with the whole fraternity of ancient fathers, rejected the antipodes, as a wild chimera, dangerous to religion. "Far be the thought from all Christians, however," concludes this ingenious naturalist, "that a religion so true, so holy, so transcendent, should have any thing to fear from the progress and the improvement of the sciences!"

LETTER VIII.

I WOULD here willingly release your attention from fanciful fictions; but the abundance of ingenuity which has been bestowed upon theories of creation, renders it impossible. We will for, a moment, therefore, glance at the system of a most brilliant and eloquent philosopher; one whose labours, indeed, have added lustre to science, but whose impetuosity of imagination hath generated error, as wild and unsubstantial as any of his predecessors

"The earth," says Buffon, "was originally in a state of liquefaction, the greatest part of the materials of which this globe is composed being vitrifications, or vitrifiable by fire. It assumed its figure when in a fluid state. The diameter of the earth is about three thousand leagues, and it is situated about thirty-three millions of leagues from the sun, round which it revolves. This annual revolution is the effect of two forces; the one may be considered as an impulse from right to left, or from left to right; the other as an attraction from above downwards, or from below upwards, to a common center. Gravity is the general law of nature. The planets, the comets, the sun, the earth, are all subject to its laws. The centrifugal force, or force of impulsion, is still unknown: but it is evident, as the attractive force continually draws all the planets towards the sun, they would fall in a perpendicular line into that luminary, if they were not kept at a distance by some other power, forcing them to meet in a straight line. If again this impulsive force were not counteracted by that of attraction, all the planets would fly off in the tangents of their respective orbits. The motions both of planets and comets are regulated by impulsive and attractive force, continually acting and obliging them to describe curves. May we not conjecture, therefore," says Buffon, "that a *comet falling into the body of the sun*, might *drive off* some parts from its surface, and communicate to them a violent impulsive force, which they still retain? The earth, when it issued from the sun, was liquid fire. When it cooled, the vapours, condensed, fell down in the form of water upon the surface, depositing at the same time a slimy substance mixed with sulphur and salts, part of which was carried by the motion of the waters into the perpendicular fissures of the strata, and produced metals, and the rest remained on the surface, and gave rise to vegetable mould, with more or less of animal and vegetable particles. Thus the interior parts of the globe were originally composed of vitrified matter, and they continue so at present. Above these were placed those bodies which the fire had reduced into the smallest particles, as sands, which are only portions of glass; and above these, pumice stones, and the scoriæ of melted matter, which gave rise to the different clays. The whole was covered with water to the depth of five hundred or six hundred feet. This water deposited a stratum of mud, mixed with all those matters which are capable of being sublimed or exhaled by fire; and the air was formed of the most subtile vapours, which, from their levity, rose above the water."

"Such was the condition of the earth, when the tides, the winds, and the heat of the sun began to introduce changes on its surface. The diurnal motion of the earth, and that of the tides, elevated the waters in the equatorial regions, and necessarily transported thither great quantities of slime, clay, and sand, and by thus elevating these parts of the earth, sunk those under the poles about two leagues. The strata are not arranged according to their specific gravities. Beds of heavy matter are frequently placed above those of lighter. Rocks are often upon clay and sand. Glass appears to be the true elementary earth, and all mixed bodies are only glass in disguise. Every grain of sand may be considered as a small flint, and every piece of flint as a collection of fine sand cemented together. The quartz is perfectly transparent flint, and in decomposing, produces soft talcs, or stones, composed of plates, generally parallel, flexible, and elastic. Great mountains, which are composed of vitrescent materials, and produced by the action of the primitive fire, are immediately connected with the interior rock of the globe, which is also a vitreous rock of the same kind. Every material of which this globe is composed, might in a word be in general reduced to its primitive state of glass, if a sufficient degree of heat were to be applied."

" The great inequalities of this globe," continues Buffon, " took place when it assumed its form and consistence; swellings and blisters arising, as in the case of a block of glass or melted matter. In the action of cooling, it was furrowed with depths and eminences. The vitrescent matter, of which the rock of the globe is composed, and all the nuclei of mountains, were produced by the primitive fire. The waters have only formed the accessory strata, which surrounded the nuclei horizontally, and in which are the relics of shells and other productions of the ocean. Shells never having been found on the highest mountains," says Buffon, "nor any where much above two thousand fathoms above the level of the sea, it is clear that the waters never surmounted those high summits, or at least remained but a short time upon them. They only formed hills and calcareous mountains, which never rise to much more than the height of two thousand fathoms."

"The earth possesses an internal heat," continues this naturalist, "which is peculiar to itself. The heat conveyed from the sun is small, and would not be alone sufficient to support animated nature. At equal depths this internal heat is invariably the same, and it appears to augment in proportion as you descend. The constituent parts of the globe are homogeneous. All the particles are united by mutual attraction. Every particle, therefore, is a center, and there is no reason to believe that the parts which surround the center, are denser than those which surround any other part: neither should it be imagined, that the interior parts of the earth are hollow; they are composed of matter of considerable density, nearly similar to that of its surface."

Such, in brief, is the skeleton of Buffon's system. I have not conceived it of importance to exhibit the subject in its full proportions. The investigation would have been tedious; and the display, however in its detail beautiful, too feebly supported by clear and probable reasonings, to be otherwise amusing, than as the fairy wanderings of an ardent and fertile imagination.

The physical objections to Buffon's system are strikingly apparent. As to the fragment dashed from the sun—this I shall leave to be examined by others. The manner of accounting for the oblate spheroidical figure of the globe, may deserve your consideration. Mathematicians have different methods by which they explain this figure.* The great Newton deduced it from a centrifugal force, and the French philosopher, with various others, have followed him. But, notwithstanding such high authority, it has been contended, that we should never treat of this

* Jones's Philosophy of the Elements.

this globe as if it were exposed to certain artificial forces, independent of the natural forces of the elements, in which it is involved, and by which it seems to be governed. Had it been every where acted upon by equal forces, say these writers, the result would have been a perfect sphere; but as the forces must have been unequal, the consequence must be an inequality in its figure. The equatorial parts would necessarily be exposed to a greater degree of heat: they would therefore be rarified; and the polar parts, being subjected to a colder medium, would be more compressed; in consequence of which the polar diameter would be shorter than the equatorial; and this consequence seems absolutely necessary. Hence, it would be unphilosophical to suppose, that the earth could be equally affected in all parts, when it is so unequally circumstanced; and it would be still more so to suppose, that the elements which invest it, had no effect upon its constitution. The exposure of the earth's orb to the sun, is a circumstance, whence some difference must arise in the several parts of it.

In regard to the vitreous state of the globe, all its parts speak so loudly against this doctrine that it is almost unnecessary to descend to particulars. In what manner could the calcareous and vegetable matters have so accumulated in the bowels of the earth, had it been originally vitrescent? Or how could the innumerable strata of other heterogeneous substances, so regularly and so effectually have fixed themselves in the very heart of this glassy matter?

If every thing indeed we see, and every thing we do not see; if all the earth, the mountains, the rocks, the stones, the trees, the flowers, all were originally of the substance of glass, the human frame itself must likewise have been of glass: man and beast must have been of the consistency of a bottle. A whimsical idea this, but still one for which Buffon, had he warily looked about him, would have found a solution. Becher was, many years before him, perfectly acquainted with animal glass. He tells us in unequivocal terms, "Homo vitrum est, et in vitrum redigi potest, sicut et omnia animalia." He regrets that those nations who drank out of the skulls of their enemies, had not been acquainted with the art of converting them into glass. He even shews that it would be possible to form a series of one's ancestors in glass, in like manner as you could have them in statuary. A skeleton of nineteen pounds," says he, "burned, affords five pounds of phosphoric glass." But the fact is, that granites and flints cannot be formed by fire. "I will allow," says Bergman, (and whose authority is greater than Bergman's?) "that chrystals may be produced by the dry method, and I know several ways of obtaining them both by fusion and sublimation; but I can never be persuaded that the zeolite has been produced by the assistance of fire: or that a granite, which consists of clear quartz chrystals, solid feld spar, and mica, could have been able to support a fusion without the quartz bursting or becoming opaque; or the feld spar becoming soft and liquid, which it even does in a weak fire.

As to flints, it was for a long time, and by many, as well as by Buffon, supposed that they were the production of fire, and of a sudden condensation. It was even averred, that flints could be artificially made by a process of fire; and the truth of the opinion was rested on flints never having been found to contain petrifications, or the marks of any organized body. But, on better observation, the reverse is found true; for nothing is more common in cabinets, than flints containing not only petrifications, but even marks of organized bodies, surrounding the petrifications. Moreover, not the smallest trace of the action of fire is ever to be discerned, either in the flints themselves, or in the substances which contain them. On the contrary, calcareous substances are in general found where flints are embedded; which is of itself an unequivocal and satisfactory confirmation of their formation in water. "Madrepores, and fossil shells, with other calcareous matters," says Rome de l'Isle, "form themselves into silex, in proportion as the fixed air, which is a constituent part of their substances, is disengaged by some other acid, and is replaced by that acid. Hence quartz, agate, silex, and flint, according to the degree of homogenity, which the aggregate of the new combination has acquired. Nor is it uncommon to find a shell the nucleus or the mould of a silex; the interior part filled with crystallizations of quartz; and the surrounding mass, a common agate or flinty substance." "In the neighbourhood of Beauvais in France," says Monnet, "silex is to be found in abundance, exhibiting all the marks of the different passages de la craie, a l'état de la pierre a fusil. I express myself so," says he, "because I think it cannot be doubted that chalky or calcareous matters, are those from which silex is formed." Cronstedt is of the same opinion.

LETTER IX.

ALTHOUGH Buffon erected so unsubstantial and frail an edifice, he yet is to be revered for the success with which, in conjunction with M. Daubenton, he exploded a multitude of absurdities; and for the very close manner in which he in other respects followed nature. The supposition of Buffon, which was embraced with some little variation by Hollman of Gottingen, that the waters of the ocean, by their own weight, had burst into caverns beneath, and so separated land and water distinctly, was some time after its publication boldly opposed by Mons. Raspe, the editor of the posthumous works of Leibnitz.

M. Raspe held it to be absurd, to suppose the existence of such immense caverns as would swallow up so much water, as was necessary to leave dry mountains upwards of twelve thousand feet above the surface of the sea. He reprobated the idea, which had been generally held by naturalists, that the surface of the sea is considerably lower than it was formerly: he insisted on the credit of Donati, that it is higher than it was in ancient times, at least at some places. He said, neither the actual conformation of mountains, with their different inclinations of strata, nor the regular figure of the hills, with their correspondent angles, are at all explicable on Buffon's system. "It is not to be conceived,' says he, "in what manner the waves of the sea, after having raised up a quantity of sand, earth, stones and shells, should deposit them again in horizontal and parallel beds." The laws of hydrostatics do not appear to admit of the possibility of any such method, and still much less of the existence and action of those torrents at the bottom of the sea, which the French naturalist conceives to penetrate the strata of the mountains formed there, and to open a passage through, to divide them into hills and vallies. Besides, it has been asserted by many, particularly by Doctor Tozzetti, an ingenious Florentine, that the sea is much calmer, or has less motion at the bottom, than in any part nearer its surface.

In rejecting Buffon's system, however, Mons. Raspe did not admit of those terrible volcanos of the Abbé Moro, who affirmed, in some respects after Mr. Ray, that both the earth in general, and its mountains in particular, rose from beneath the sea, from the effect of subterraneous conflagrations, earthquakes, and volcanos, which threw up their substances in confused heaps into the waters, wherein they have successively subsided, according to their different specific gravities. The regularity of strata, mixed with innumerable marine animals, observable over the whole face of the earth, sufficiently refuted this hypothesis. He had observed, likewise, that in veins of sand, marble, chalk, marble and slate, we find no indication of a burning soil, or of combustible substances; but, rather of a sediment disposed by the agitation of the sea. At the same time he remarked, that he never had met with any marine substances or animals in a stratum of cinders or of pumice stone.

M. Raspe further imagined, that the strata of which the surface of the earth is compounded, were originally formed at the bottom of the sea by the constant agitation of the waters, and the continual production and dissolution of plants and shells; after which, the subterraneous explosions and earthquakes, breaking through the bottom of the sea, not only formed banks, hills, and submarine mountains, of its broken parts, but frequently raised it up with its incumbent strata, in sufficient quantity to form islands and dry mountains. He conceived that, at other times, the pressure of the water occasioned it to break through into the cavities thus made by previous eruptions; that at others, again, the violence of the subterraneous explosions was so great, as to remove such mountains from one place to another; while the heat of the fires was so intense as to melt, calcine, or convert the adjacent substances into stone.

The present crust of the globe, indeed, is not, it may be believed, (here we may safely join issue with Raspe) the same with the primitive crust, or the matter with which the earth was covered at the creation. The surface shews very evident marks of variety of revolutions. In some parts, the crust consists of regular beds of earth, of sand, of gravel, of stones, placed horizontally, but not specifically according to their respective gravities. In other parts, it is a mass of heterogeneous matter, which might appear to have been thrown together by hazard: earths, sands, flints, shells, confusedly huddled, and in the midst of them animals and vegetables. How these things were brought about, it is not easy to determine. It is, however, clearly contrary to every observation, to suppose, that each individual stratum forms a zone, or rather a shell, which stretches quite around, and envelopes the whole globe, like one of the coats of an onion. Strata are found in all directions, horizontal, perpendicular, oblique, even sometimes waving up and down for a short way like a high sea on the abatement of a storm. Raspe's doctrine is thus found not to be free from difficulties. The production of mountains was too rare a phænomenon, to support a general theory: and moreover, the few islands and mountains which had been so formed, were not composed of parallel strata, but almost always consisted of irregular combinations.

In opposition to Buffon, De Luc also came forward about the same time with Raspe, with strong and well pointed argument. This writer supposes that when the sea covered our continents, it had a mountainous bottom, which neither the waters, nor any known cause had formed, and which he calls primordial. Some of these mountains arose above the surface of the sea, and formed islands. These islands and the ancient continents were fruitful, and were peopled. The ancient sea, which covered the modern ones, had its tides, its currents, and its tempests. These powers, acting on soft matters, produced accumulations of calcareous substances, mixed with marine bodies. The rivers, in the mean time, carried to the sea scattered fragments of terrestrial vegetables and animals; the sea itself washed them off its coasts; and these materials, transported by its currents, became a secondary soil upon the primordial bottom.

"Fires and elastic fluids," says De Luc, "formed by the fermentation which the waters, filtrated through these bodies, produced, made various openings in the bottom of the ocean, whence proceeded torrents of liquefied substances and lava, which gave rise to the volcanic mountains observable on the surface of our continents. These excavations, when large quantities of elastic fluids were engendered, at once produced earthquakes, which shook even the mountains, and occasioned in them chinks and openings. These chinks were prevented from closing, by the ruins that fell into them from the sides of the mountains, and being afterwards filled with heterogeneous substances, in whose composition the sea water and subterraneous fire may have concurred, exhibited veins, in which, since they have been dried, the filtration of the waters has produced a variety of changes, of which many are observable. The bottom of the ancient sea had under it caverns. The subterraneous fires reducing, or piercing them, they fell in from time to time. Hence the gradual sinking of the sea beneath its level. The ancient continents being placed over caverns so replete with fermentation, their props fell in, and they themselves disappeared."

" At the end of this first part of the great revolution," continues this philosopher, " the sea covered all the globe, except the islands of its ancient bottom, which increased in number and magnitude, but continued still separate, until the weight of the water, added to that of the superior vaults, crushed the inferior ones, and deepened more and more the new bed of the ocean; so that at last by a motion, rapid though not violent, all the waters withdrew from their former bottom, and left our continents dry. As soon as our continents were thus delivered from the waters, the fermentations which they produced, in combination with fire, and other physical agents, ceased. The old volcanos were therefore extinguished, and new volcanic eruptions arose in the new bed, to which the waters withdrew. The two general sources whence the new earth (our present continents) received, in consequence, the germs of fertility and population, were the plants, seeds, and animals that the sea, during the great revolution, carried off from the sinking continents, and which, driven by the winds and waves, were thrown upon the ancient islands (our present mountains) in proportion as they arose out of the departing ocean, and afterwards upon the borders of the new continents."

These deposited materials of vegetation continually accumulated; the change of vegetables into turfy earth; the diminution of fertility on the high mountains, from the accumulations of snow and ice; the waters of the mountains by the mouldering parts; and the substances which the rivers carry into the sea:"—these are the five classes of phænomena which De Luc with considerable ingenuity employs, to prove the recent origin of our continents; and to shew, that the present state of the earth's surface is not of a very ancient date. He refutes Buffon and Miran's notion of a heat peculiar to the earth; the one attributing it to the earth's being a piece of the sun, and the other to a central fire. He demonstrates, that the sun is neither a liquefied and burning substance, nor could be put in fusion by the motion of comets around him; that the earth was not originally liquefied matter; that all Buffon's fancies relative to the vitrified matters of the earth grown hard, are unphilosophical in theory, and false in fact; that Buffon's notions concerning the formation and changes of our continents by the motion of the sea from east to west, and also that the waters may again cover all parts of our globe, are contrary to the principles of hydrostatics, and to the authority of natural history; that it is not true, that the seas diminish in volume, or sink gradually beneath their level; and that the successive cooling or refrigeration of the earth is a groundless notion.

"Mountains, on the contrary," continues De Luc, "were formed in the heart of the ocean: the flux, reflux, and currents indisputably aggregated large quantities of matter, and formed these mountains at the bottom of the sea." But it was asked this philosopher, could the flux, the reflux, and the currents dispossess these mountains of the surrounding waters, and exhibit them dry on the face of the globe? The sea, he must acknowledge, is always at the same level; the motion of its waters is horizontal: wherefore, without some other cause than these, mountains must have continued in their pristine state to eternity. To this De Luc replied—

"There are many mountains, indeed, which have not the smallest appearance of being formed under the waters, and this fact causes an insurmountable difficulty in classing mountains.—Some have visibly been formed by successive depôts in the sea: but on the contrary, there are others which have not the smallest vestige of such an origin; or if they were created in the sea, must have had some other cause than that of successive depôts, and have preceded the existence of marine animals. But in truth," says he, "there is no occasion to have recourse to different continuances of the ocean on our continents, for the explanation of the formation of the secondary mountains. The revolutions which the bottom of the sea must anciently have undergone, and the cones of volcanos, are sufficient to account for the formation of the secondary mountains. From these revolutions, different depôts must have arisen in the same places, or in neighbouring situations. As to the different nature of matters, whether vitreous or calcareous, these transmutations may be conceived to have been produced under the waters, without having recourse to marine animals. Neither do I insist upon this," says De Luc, "if it shall be in any manner objected against me. It is very difficult to determine on such points:

at the same sime, I will never allow that vitreous could have preceded calcareous substances."

"If I compare mountains of granite and of marble," says De Luc, "I have no difficulty in ranging them in their proper classes. Granite is a hard substance which gives fire with steel; marble is soft, and can be scratched with a knife. Granite, exposed to a certain heat, is reduced to a glass; marble is reduced to a lime. Granite resists an acid; marble is corroded by it. It appears then that these substances are totally different. As to their formation, granite has no beds which can mark it to have been raised by accumulations: whereas, on the contrary, marble is always in beds, and besides has manifest tokens of having been formed by accumulations at different periods. The crystallization which are found in granite, are almost always of a siliceous substance, quartz: whereas marble has always spath, which is a calcareous one. In granite, there are mines of tin; but tin is never found in marble. In marble, marine bodies have always been found; in granite, never. Thus, of these two sorts of mountains, the one offers nothing which can authorise us to suppose it formed in the sea; and the other offers every thing to ascertain such formation. The former then I call *primordial* and the latter *secondary* mountains: and in places where they are intermixed, it will invariably be found, that those which have been formed in beds, and which contain marine bodies, often cover those of the other class, but are never found covered vice versa. But besides these," says De Luc, "we find accumulations of slate lying horizontally, or a little inclined, which contain between their laminæ the impressions of foreign bodies, such as shells, fishes, vegetables. These undoubtedly are secondary mountains. Other slates, again, are found with their beds vertical, and without either vestiges or marks of other substances. Another species of mountain, likewise, is that which is composed of a sandy stone, and has no traces of marine animals, and which, in their intermixture with the primordial mountains, often cover them, but are never covered by them. Is it not possible, then, there may be parts at the bottom of the sea, where there are no animals, or where no animals chuse to live?

"The greatest mountains on the globe," continues this writer, "were not formed under the waters; they owe their origin to some other cause; and they are by far the most numerous. The Alps, the Apennines, the Pyrenees, and I doubt not, from what Mons. de la Condamine, says, the Cordelliers are of this primordial class. It is agreed, but erroneously, that these primordial and secondary classes of mountains must have existed at the bottom of the sea, and that the latter (by being found intermixed, and by reposing on the former) must have been creating in the ancient ocean, at the time when the primordial ones were arrived at their full size. The real fact is, however, that the sea makes two sorts of mountains, in their nature totally different. The one is formed at its bottom; the other, on its shores. The latter arises every where, from light moveable substances being pushed from its interior to its exterior. For, let the wind blow from whatever quarter of the compass it may, when there are waves, they will always roll towards the shore: and the tide also daily drives substances before it, which the reflux never carries back. Thus, by both one and the other of these causes always acting, there must be collected on all shores, where there are not currents, shelving banks.. As to *volcanic mountains*, the manner in which they are generally formed is this:—A mouth of fire is opened in a low place, that is to say, on the level of the soil: that mouth vomits a quantity of burning matters; some of which run in lava, and others, thrown into the air, fall under various denominations. These different matters, in accumulating, form a cone, the necessary shape given by accumulated substances falling from the same given point. So long as the original mouth is fed, and keeps open for the discharge of the fiery contents of its bowels, the cone continues to increase: but should it be stopped, the explosive matter finds its way latterally, and thence forms little mountains. Almost all islands are now looked upon to be volcanic productions in the sea, of this nature; and the calcareous and volcanic matters found in them, intermixed with shells and impressions of fishes and plants, prove it demonstrably."

"On the night of the 29th of September, 1538, after two years of almost continual earthquakes, and above all, after a day, during which the earth was constantly agitated, an opening was forced in the middle of a fertile plain, out of which issued fire, stones, and sand, which formed the little mountain called *Il Monte Nuovo.* It occasioned the ruin of many edifices, of fields, men, and cattle; and buried under its accumulated matter, the whole Burgh of Tipergola. It is about three miles in circuit, and a quarter of a mile in height."

LETTER X.

THE explanation, which had been given of the production of certain mountains by volcanic eruptions, was afterwards, by very intelligent men, applied to account for the existence of all mountains whatever. Mons. Pallas undertook to refute, by what he conceived undoubted facts, the antiquated opinion, that mountains arose from the waters. He travelled, by order of the Empress of Russia, through her dominions in Europe, and in Asia; and during the course of a minute and fatiguing investigation, found that the majestic primitive chains of mountains of Siberia were all granite with a basis of quartz, more or less mixed with spars, mica, and little portions of basaltes, scattered without order, and in irregular fragments. This ancient rocky substance, and the sand produced by its decomposition, he held to be the basis of all our continents. This granite he never found lying in strata or beds; it was either in blocks, or in masses, accumulated upon each other, and never exhibiting the least mark or vestige of petrifaction,

faction, or of organical impression. Besides which, he maintained, that in addition to these primordial mountains, there were others of a more recent origin. These he called secondary and tertiary: the former, which were schistous, he said, were produced at the sides of the primordial mountains, by the decomposition of the granite; the latter arose from the wrecks and contents of the sea, raised and transported by volcanic eruptions, and consequent inundations.

On an hypothesis somewhat similar, others have ingeniously contended that mountains were incontrovertibly produced by volcanos, and not volcanos by mountains. "The entire basis of the Island of Ischia," says Sir William Hamilton, "about eighteen miles in circumference, is formed by lava. The great mountain in it, formerly called Epomeus, and now San Nicolo, which is nearly as high as Vesuvius, was thrown up by degrees, and the entire island has arisen out of the sea." The same creation he gives to Vesuvius itself. "For why," said he, "should not Vesuvius, in a succession of ages, rise to two thousand feet, when it is well known Montagne Nuovo, near Puzzole, rose out of the Lucrine Lake in one night? But, as I have already said, this was no new doctrine. An Italian writer published a book at Venice in 1740, in which he maintained that mountains had been raised in the sea by subterraneous fires, and had carried with them the shells of fishes, and other marine bodies usually found at the bottom of the ocean. Even in *Hooke's Discourse on Earthquakes*, published in 1688, mention is made of the bottom of the sea having been raised by subterraneous fires; and he accounts for the shells which are found on mountains from that principle, and thinks it not improbable that earthquakes were instrumental in occasioning the deluge. But, a mountain at Taberg in Sweden, said to consist entirely of *iron ore*, (the only ore, by the way, of which entire mountains have ever been found to be composed) four hundred feet high, and in circumference about three miles, seemed to admit of no positive explication, but on the contrary, went to the solid conclusion, that no hypothesis proposed for the formation of mountains had yet proved satisfactory, or free from contradiction. No ore was found beyond the foot of this mountain. It appeared as if it had been artificially laid upon the land; and yet the bones of animals were found in its interior fissures.

It is no doubt a matter of fact, that there are some eminences on this earth, improperly called mountains, which are little else than heaps of cinders and of pumice stones, cast up by eruptions, but aggregated and settled into masses. Yet, such are no sufficient refutation of the opinion, that volcanos, so far from being causes to operate to the raising of mountains, are directly the reverse, and most decidedly tend to their lowering and destruction.* The earth is rather depressed than elevated by forces from beneath. —No volcano, or earthquake, ever produced, within the knowledge of man, what should be called a mountain. The shock would be too great for the globe. In all the tremendous accidents, which have happened within the memory of record, has there ever been one, whence proof can be deduced that a granite mountain has been raised? The contrary I should suppose to be the case. Moreover, the configuration of their internal parts renders it incredible, that structures so uniform and regular, should have been produced by sudden explosions, or desultory succussions of the earth.

Borelli on this subject observed, that the fire of a volcano neither proceeded from the center, nor from the bottom of a mountain, but from the top; and that the inflammation never kindled but at a small depth. Buffon adopted the same opinion, and maintained, that the materials which issued from volcanos were always the same with those on the top of the mountains, only disfigured by calcination, and the melting of the metallic particles they contained. "Fire," says he, "it is known, acts equally on all sides. It cannot therefore act upwards with a force sufficient to throw large stones half a league high, without an equal re-action on the base and sides. Why, then, if the volcanic matter lies deep, does it not issue out of plains, where the resistance is less than on the top of mountains? This is not inconsistent with their being the cause of considerable earthquakes, nor with their communication by subterraneous passages. It is not difficult to discover the reason why volcanos appear only in mountains. Greater quantities of minerals, sulphur, and pyrites exist in mountains than in plains. Mountains are more subject to the impressions of the air, and receive more rain and moisture, by which mineral substances are capable of being fermented to such a degree as to produce actual inflammation."

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* Buffon.

But, ingenious as this idea is, it is not satisfactorily founded. Fire must be supposed much deeper than either the centers, or the basis of mountains. Buffon, indeed, acknowledges, that volcanos never exist but in high mountains; but yet he supposes that some are connected with others by subterraneous passages, the eruptions not unfrequently happening at the same time. "Volcanos," says he in his figurative language, "are immense caverns, with apertures often of more than half a league in circumference; and certain fanciful writers have considered them as vents to the central fire." Whatever others might have said upon this subject, or whatever Buffon himself might have conjectured, the fair result of investigation seems to establish that volcanos, (and they have been peculiar to no climate) had neither a necessary, nor, in general, an accidental connection with other mountains.* With the sea, indeed, they invariably appear to have had the closest and most inseparable alliance. All such as have been traced in a living state, have been found, in general, in the neighbourhood of the sea. Those extinguished, though in the inland parts of countries, afford convincing proof that the sea has been in their vicinity, when they probably were in their strength. In Peru, they rest upon granite; in Hesse and Bohemia, on schistus; in Silesia, Italy, and other southern parts of Europe, on lime-stone; and all these substances are indisputably of aquatic origin. Subterraneous fires have existed universally in the bowels of the earth; and there is scarcely a country, where the ravages they have occasioned, are not to be traced. Mons. Condamine, in 1755, writes, that all the hills and mountains about Naples are huge heaps of matter vomited by volcanos, which are now extinct, whose eruptions, anterior to history, seem to have formed the ports of Naples and Puzzoli. He could trace lava the whole way from Naples to Rome. "It is impossible," says he, "for any one not to be satisfied of a perfect resemblance between the productions of Vesuvius and those he will meet with at every step in his way from Naples to Rome; from Rome to Viterbo; and from Rome to Loretto. When I see on an elevated plain," continues he, a "circular bason, surrounded with calcined rocks, the verdure with which the neighbouring fields are covered does not impose upon me; I instantly perceive the ruins of an ancient volcano. If there be a breach in the circle, I find out the passage of the torrent of lava. If there be no breach, the rain and spring waters, which assemble there, having no issue, generally form a lake in the mouth of the volcano. I look upon the Apennines and Cordelliers as a chain of volcanos. I do not, indeed, affirm that all mountains are so. I could not observe the same appearances in the Alps; but I have found the same in Dauphiny and in Provence; and most countries afford instances of it."

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* Kirwan.

What Condamine says, is certainly just.—The coast of Pausillipo, at Naples, the Capo de Monte, and the whole mass through which the catacombs are excavated, are all indurated tufa & piperno, which is so readily distinguished by its fragments of close grained lava. The shores from the ruins of Pompeia to the sea, for the distance of two miles, are known to be formed of pumice stone, pozzolano, and cinders, that fell in the year 79. In short, the whole sweep of the bay of Naples, from Stabea to Baia, is nothing more than volcanic matter, meliorated by time and culture into vegetable earth. On this subject Micheli published in 1733. He was the first who pursued the traces of volcanic productions among the Apennines, particularly in the neighbourhood of Radicofani. The observations of Condamine, however, seemed to establish one strong fact, namely, that the Alps has not the smallest vestige of a volcanic origin. Notwithstanding all this, the theory of the volcanic formation of all mountains was for a long time supported. Philosophers struggled for their opinion with a violence resembling that of their favourite element. But they were at length staggered. Farther observation gave increasing probability to Condamine's ideas relative to the Alps. Mons. De Saussure, the intrepid and respectable ornament of science, at present at Geneva, particularly supported them in one of his publications. "Jusques à ce jour," says this able man, "on n'a trouvè aucun vestige des volcans, ni dans nos environs, ni même dans toute la Suisse; & qu'aprés avoir visitè moi-même en bien des endroits, & avec l'attention le plus scrupuleuse, toute cette partie de la châine des Alpes, qui s'étend depuis Grenoble jusques à Inspruck, je n'ai pas apperçu, à l'exception de quelques eaux Thermales, le plus lèger indice de feux souterrains." But, of this, we shall have much more to say hereafter; I shall, for the present, merely remark that De Saussure himself has, since this publication, discovered indisputable volcanic remains, not, indeed, immediately among the Alps, but, in fact, not very distant from their neighbourhood.

LETTER XI.

FROM the preceding letters you will, I fear, have been wearied with theories and systems of the earth; but the exhibition was necessary. Nor can you now be released until two ingenious philosophers of your own country, Mr. Whitehurst and Doctor Hutton, together with their hypotheses, shall have been introduced to your acquaintance.

Mr. Whitehurst supposes that not only this globe, but the whole of the planetary system, was once in a state of fluidity, and that it acquired its oblate spheroidical form by revolving round its axis in that state. "Each orb," says he, "has its equatorial diameter greater than its polar. Each is subject to the same laws of gravity and centrifugal force. Consequently the earth, if it were created, must have been brought into existence in a solid or a fluid state. If solid, it must have been dissolved, and yet no universal dissolvent has been found in nature. Fluidity, therefore, was its state, and that fluidity was owing to the first assemblage of its component parts. The component parts," continues he, "of the most dense bodies become suspended in whatever menstruum they are dissolved — Gold in aqua regia; silver in aqua fortis; salts in water; and water in air. The component parts of the earth were thus suspended in one general undivided mass or pulp, 'without form and void,' This was the chaos. These parts were indued with a variety of principles or laws of elective attractions, though equally and universally governed by one and the same law of gravitation. They were heterogeneous, and by their attraction, progressively formed a habitable world. Not, indeed, that God was unable to have formed an habitable world in a moment, To him every thing was possible. But, as man can judge only of modes, so by modes only can he conceive a creative operation. As the component parts of the chaos," proceeds Whitehurst, "progressively separated, the sea universally prevailed over the earth; for, if during the separation of the atmosphere and the ocean from the chaotic mass, the earth had been perfectly free from the attractive influence of all other bodies, the solids would equally have subsided from every part of its surface, and consequently have become equally covered with water. But the sun and moon were coeval with the earth, and their attractive influence interfered with the regular uniform subsiding of the solids; for as the separation of the solids and fluids increased, so in like manner the tides increased, and removed the solids from place to place, without any regularity. And hence the sea became unequally deep, and those inequalities daily increasing, in process of time dry land appeared, and divided the sea. Primitive islands, thus like sand banks in the sea, became formed. And hence, as the central parts of the earth became more immediately quiescent than those remote from the center, it was to be presumed that the former began to consolidate before the latter; and, therefore, it was repugnant to the laws of nature to suppose, that the central part should consist of water only, and the more superficial of a shell or crust, as some writers had imagined. As the primitive islands, " continues Whitehurst," were more ponderous and less elevated than the bottom of the sea, may we not infer that the former more immediately subsided into the ocean of melted matter than the latter, and therefore became the bottom of the postdiluvian sea; and the bottom of the antediluvian sea being more elevated, was converted with the postdiluvian mountains and continents? A conjecture this," says he, "remarkably confirmed by the vast number of fossil shells, and other marine exuviæ found imbedded near the tops of mountains, and the interior parts of continents, remote from the sea, in all parts of the world. Hence mountains and continents were not primary productions of nature, but of a very distant period from the creation of the world, a time wherein the strata had acquired their greatest degree of cohesion and firmness; and at a time, in which the testaceous matter of marine shells was become changed to a stony substance; for I have frequently observed in the fissures of lime-stone strata," proceeds this philosopher, "fragments of the same shell adhering to each side of the clift. Some of the postdiluvian mountains, we know to be upwards of three geographical miles, or 19,026 feet above the level of the sea; whereas we cannot suppose the antediluvian hills to be more than forty or fifty feet perpendicular height above it, since they were formed by the action of the tides, as sand banks are formed in the ocean." Mr. Whitehurst afterwards goes on to the exemplification of his data, and in so doing discovers a very accurate knowledge of mineralogy, and of the peculiar properties of the several strata of which the surface of the earth is composed: but still it is not possible to subscribe to his general doctrine. For, why, for instance, must the world have been created either absolutely solid, or absolutely fluid? Why might it not have been created partly one and partly the other, as is evidently its state at present? Or why should we admit that the loftiest of the antediluvian hills could not have been more than fifty feet in elevation? Such assertions as these are too arbitrary to be implicitly acquiesced in; nor in fact are they upon any principle of reason to be supported, although they afford their author an opportunity of displaying much information and ingenuity.

This theory of Mr. Whitehurst is altogether, you will perceive, in opposition to those which had preceded him, if we except only in some instances that of Monsieur Le Cat. But a vitreous or a turbid fluidity; a world formed from a mass of burning matter, or from a mass of muddy and heterogeneous particles; each and all are far from affording a satisfactory explanation of the manner in which the God of Nature effected a creation. We might with equal propriety admit of the idea of the celebrated Doctor Halley, who, in attempting to account for the variations of the magnetic needle, by reason of a loose internal nucleus within the earth, conjectured that the world we live upon, might have another habitable world within it, surrounded by a system of subterraneous luminaries, similar to those which give light to the upper earth, but comprehended within a smaller sphere.

Next comes the theory, and I believe it is the latest that has been published, of a naturalist of eminent abilities, Doctor Hutton. His general system may be comprised in these four propositions. 1st, That all our rocks and strata have been formed by subsidence under the waters of a former ocean, from the decay and waste of a former earth, carried down to the sea by land floods. 2d, That these submarine rocks and strata were heated to the degree of fusion by subterraneous fire, while emersed under the waters of the ocean; by which heat and fusion the lax and porous sediment was consolidated, perfectly cemented, and all the cavities filled up by the melted matter, while the whole mass was in a state of fusion. 3d, That the rocks and strata, so formed and consolidated under the waters of the ocean, were afterwards inflated and forced up from under water by the expansive power of the subterraneous fire, to the height of our habitable earth, and of the loftiest mountains upon the surface of the globe. 4th, That these operations of nature, namely, the decay and waste of the old land, the forming and consolidation of new land under the waters of the ocean, and the change of the strata now forming under water for future dry land, are a progressive work, which always did, and always will go on in a perpetual succession, forming world after world.

In this theory, Doctor Hutton wisely steers clear of a rencounter with the sun; which it had been well for his predecessors if they had avoided also; and I, in glancing at his theory, will attempt to be equally prudent, and neither give a conjecture at a solar shock, nor inquire whether the center of the earth be a solid or fluid, light or heavy, dense or rare, hot or cold. I have no business with what I cannot examine. The superficies of this planet is all that is given to my inspection. Doctor Hutton, however, treads rather too much in the steps of Buffon on the one side, and of Moro on the other; and gives too implicitly into the belief of the eternity of the world; notwithstanding, he is satisfactory and perspicuous in many parts of his system. For instance, the decomposition and waste of the surface of the rocks and strata of mountains and cavernous shores, and the formation of strata under the waters of the ocean, are points which are to me evident, and which I shall have occasion to insist upon largely hereafter.

At the same time, I confess, I am far from being inclined to say, that the earthy matter, borne down by the floods, is not frequently thrown back upon the shores, into bays and creeks, and into the mouths of rivers, where it forms deltas, and in many instances, enlarges the bounds of the dry land. The Ganges, the Indus, the Nile, and various celebrated rivers, prove it. But with the wrecks of the earth in general, together with the aid of similar earth at the bottom of the ocean, I am greatly mistaken if we shall not find that that which is, might have had a submarine formation, and that which may be, may naturally be supposed to have a like progression. But, in regard to the doctrine of the consolidation of our rocks and strata, while under the waters of the ocean, by the heat and fusion of subterraneous fire, such hypothesis is too slenderly supported by phænomena, to be easily adopted. The very reverse would more probably appear to have been the case; for fire is not wanted for the consolidation of the parts of terrene substances: witness, stalactitæ, incrustations, and the numerous body of common homogeneous, and even compounded indurated matters, which are formed by the accretion of particles, accumulated and deposited by water. More of this, however, in its proper place. I have only this remark to make, that to me it is as wild to plunge to the center for an imaginary heat, as it is to mount to the sun for an imaginary glass; and that all terrene and mineral substances, with a few volcanic exceptions, point with a legible index to water, as to the chief agent of their formation.

But the very principle of specific gravity, upon which these theories are attempted to be accounted for, affords as little assistance towards their support, as their original state of fluidity can be supposed to be in their formation; for if every thing was arranged according to its specific gravity, metals should be nearest to the center, and be to the earth what the stone is to the fruit. If gravity regulated every thing, why is the earth uppermost, when, according to such reasoning, it should be under the waters?—Yet, although we are thus powerfully driven from an acquiesence in the principles of these theories, there yet comes a staggering, perhaps an unanswerable question—What must have been the constituent parts of the earth, or its general consistency, previous to its arrangement into its present form? Here, I own, we are in total darkness. It is easy for us to dissent from the admission of the solar fragment, of the central fire, or of the chaotic fluid; but what is to be substituted in their place, I am afraid, it is out of our power to discover. Let us rest, therefore, where we are. It cannot be for our interest, or our satisfaction, to investigate so incomprehensible a subject. The mystery of creation is greatly beyond the powers of our intellect.

It is wonderful indeed to reflect, and you must pardon me for again repeating it, on the hardiness of philosophers. To the mechanical erection of a common fabric, they would compare the divine formation of an universe. Is it not to be asked them, if they have ever been so circumstanced, as to see nature in any such situation, as to resemble the first arrangement of the elements; if within the circle of their little view, there ever have been worlds formed under their eye; or if they have had leisure to observe, compare, and judge of the progress of the work, from its first appearance to the moment of its consummation? "Present to Des Cartes," says L'Abbé Pluche,* "a pine apple. Desire him to begin and examine the inward frame of that fruit, and from the bare inspection to tell you, what the taste of it must be?" We have a right to demand every thing from a reason like his, which comprehends and accounts for every thing. This reason was, in the philosopher's own opinion, capable of deriving from the idea of homogeneous matter, primitively put into motion, the generation of the world, and the true structure of the planets and stars. It has seen man, animals, and all living creatures distinctly proceed from the same matter; and its knowing the cause, argues the necessity of knowing likewise the structure of the animals and plants which are only the effects of that cause. But Des Cartes, with all his knowledge, will never find out that taste in his reason, nor even in the concurrence of the elements of the fruit itself, after having analyzed and dissected it. Thus, if his reason proves altogether helpless, when from the structure of a body, which he sees and dissects at his pleasure, he is to deduce the necessity of such and such a taste; what must his attempt be, when he presumes to explain the formation of a world.

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* Spect. de la Nat.

The ancients, as well as the moderns, tortured their reason first, and afterwards their imaginations, for a solution of this inexplicable point. All in vain. Anaxagoras, it is true, in his Homæomeria, would seem to have had more than a casual glimpse of truth, for he contended for simple nature, whose elements were indeſtructible; but, he too, unluckily deviated into the regions of extravagant hypothesis, and thence produced a world, which, in its creation, was merely indebted to God for putting together such parts as already had been made, and for nothing else; as if we should say, a lion was an aggregate of little lions; an eagle an aggregate of little eagles; an earth an aggregate of little earths. But the number of great minds, which have, in all ages of the world, wandered after the elucidation of such sublime, but bewildering conceptions, is too great to be credited. Democritus, Epicurus, Lucretius, Aristotle, Gassendus, Des Cartes, with the numerous family of the scholastics, all ran into the same trackless error: and, as has been well observed, when they have taken their own reason for a judge of the structure of the world, which they were not appointed by God to construct, govern, or understand, all that they have each of them apart imagined about the chaos and the formation of the universe, has been found baseless, and unintelligible; beyond their reach, and evidently contradicted by reason and experience.

LETTER XII.

MAN, it is said, is as subject to intellectual as he is to corporeal necessities. To the energy of the mind no limits can be prescribed. Of what advantage would it be to us, were it ever allowed us to penetrate into the arcana of nature; were we permitted to unravel and trace the windings of this mighty machine; to discover the invisible powers which give it efficiency and action; to form a judgment of the first principles of the elements; even to pry into the very essence and being of infinity itself? These are evidently not the purposes for which man was created; nor, were they to be understood, could they afford pleasure or comfort to a limited understanding. I would not, however, here be understood to mean, that because certain boundaries are prescribed to the human understanding, the philosopher or the man of science is therefore to be regarded as a visionary, or a dreamer in the regions of airy and unsubstantial forms. In physics, indeed, we shall perhaps never arrive at a demonstration of the constitution of bodies, until the particular motions of their several parts shall be more accurately ascertained. But, we may yet approximate, though we do not arrive at a certainty that is demonstrative: and he who gives the most probable reason for the apparent operations of nature, and makes us believe that such an effect might have proceeded from such a cause, though we are not mathematically certain of it, is yet of respectable ability and is entitled to our gratitude. Moreover, what sacrifices does not the learned and the studious man make for the improvement of knowledge, and the conveniency and satisfaction of his fellow-creatures! Too frequently unpossessed of any other than the scanty means resulting from incessant labour, he eagerly, but in indigence, prosecutes his avocation, while thousands roll in affluence from the usefulness of his discoveries. Like a body luminous and vivifying, he may be said to enlighten and cherish the world at the gradual expence and exhaustion of his own substance. While we reluctantly, therefore, are led to disapprove of imaginary systems and speculations, let us not forget our obligations to the philosophers who have gone before us. We owe them much: we owe them at least the blessings of civilization, and of morality, together with numberless benefits, the result of physical experiment.

In the display of the hypotheses of the formation of this globe, which I have already troubled you with, I have unavoidably been obliged to dissent from the premises and conclusions of each, and almost all of them. Justice then, and fair dealing, require that we should endeavour in some measure to fill up the void which we have left. The undertaking is, indeed, a hazardous one, but it would be cowardice to shrink from it. The task we shall find arduous. But, as in traversing a strange country, banks covered with flowers are often discovered in the midst of foaming waters, and enticing groves on the summit of inaccessible rocks, so shall we have the amusement of objects, at least perceptible, through the medium of common sense, and through the range and precincts of common nature.

This globe, independent of the elements with which we are acquainted, exhibits to us four grand and important particulars: a great antiquity; accidents of inconceivable extent and force; the almost certainty of the pre-existence of terrestrial places; and the renovation of the human species. We know, indeed, only the surface. The rind of the earth alone has been penetrated; the greatest caverns, the deepest mines, do not descend above the sixteenth thousandth part of its diameter. Our judgment, therefore, is confined to the upper stratum.* In this coat we find animals, vegetables, minerals, and common material substances. But how little is the information which they can give us concerning the internal strata of the earth! The contemplation of this upper surface is to the component principles of the whole, as the scales of fishes, the feathers of a bird, or the epidermis of a man would be in relation to the bones and muscles, the veins and arteries, the circulation of the blood, and the several secretions of the animal œconomy.

Thus then we see, to what an infinitely greater extent the mind can range into causation and into the universe, than it can into the sphere on which it is placed. Boundless space it may endeavour to force open to its examination. Suns, worlds, planetary existence—all it may strive to draw within its grasp, while its efforts on its own soil are confined to the scanty limits of not four miles elevation above the surface, and not even in the ocean itself, of probably more than three miles beneath the general level of the waters. But what is it which fills up the tremendous space that lies hid between pole and pole, and the still more extended equatorial mass? From the properties of a film, (and can we give it any more appropriate term) shall we presume to judge and determine on the form and texture of the internal and central parts? In the eye of analogy, is there any thing which can lead us to suppose the center to be either positively solid, positively fluid, or positively igneous? The assertion of either one or the other would be extravagant. But system maker—take your globe, elevate your mountains, sink your caverns, excavate your oceans—what now are these to the comparative proportion of the whole sphere? Not more, than to our common optics, is the down on the feather of a moth's wing, or the impression of the bee on the bell of the woodbine.

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* Bishop Watson.

From every appearance, indeed, we have reason to conclude, that the surface of our globe is not only at present upheld by shattered and hollow domes, but that our very towns and cities have their foundation in ruins. Imagination here needs not be appealed to. We have proof in the records of disastrous history. "In one night," says Pliny, "twelve cities of Asia were struck down by a succussion of the earth." "An earthquake in Peru," says Fournier, "reached three hundred leagues along the sea shore, and seventy leagues in land: it levelled the mountains as it went, threw down the towns, turned the rivers out of their channels, and made an universal havock and confusion. What vaults and caverns under such a continent! what monstrous chasms, which could receive a fractured and sinking country for nine hundred miles in extent! It would really be dreadful, as it has been remarked, if the imagination could penetrate to such hidden recesses. How tremendous would be the scene! We should find cauldrons of a mile in extent, perhaps of several miles, with a fiery mass larger than a living eye could comprehend, rolling furiously about, with flashings brighter than the sun, and bellowings louder than thunder. We should see the earth undermined, and breaking in upon the fire, with fresh stores of combustible matter, and veins of water pouring in at the same time upon the burning mass, the blasts of which, when repelled by such an immense fire, would drive before it stones, ashes, cinders, and every matter that should obstruct its progress."*

Notwithstanding this frightful picture, we yet reside upon these awful ruins, in perfect content and security. On a cursory view it must be acknowledged, the surface of our earth exhibits no great regularity or order. In its outward appearance, it strikes us with heighths, depths, plains, seas, marshes, rivers, caverns, gulfs, volcanos, and a vast variety of other discordant objects; in its inner, with metals, minerals, stones, bitumens, sands, earths, waters, and matter of every kind, seemingly placed by accident. Yet all these apparent deformities are absolutely necessary to vegetation and animal existence. Were the earth's surface smooth and regular, we should not have those beautiful hills which furnish water. A dreary ocean would cover the globe, which would in such case be suited only for the habitation of fishes. As it is, the motions of the sea and the currents of the air are regulated by fixed laws. The returns of the season are uniform, and the rigour of Winter invariably gives place to the verdure of Spring. Men, animals, and plants, consequently succeed one another, and flourish in their destined soils.

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* Philosophy of the Elements.

LETTER XIII.

FROM what has already been offered to your attention, you will perceive, that I consider the study of the elements as the greatest, and at the same time the most profitable part of natural philosophy. It is the most instructive, and unquestionably the most useful. Yet before we come to treat of the elements in detail, it will be necessary for us to look at one or two opinions relative to certain properties of our globe, which from the earliest ages have occasioned controversy; and which have been by moderns only revived. The *indivisibility of matter* is one, and not one of the least. Anaxagoras seems to have been one of the earliest philosophers upon record who held this doctrine. Aristotle borrowed it from him. Plutarch says, Aristotle also thought that bodies were capable of being divided *in infinitum*. Democritus was of the same opinion: he thought it possible that the world might be made from an atom. And the foundation of this system was, that nothing can be derived from nothing; that nothing can be annihilated;

and that there are certain eternal and incorruptible principles, such as atoms, and a vacuum; the former eternal, solid, and indivisible; the latter eternal, infinite, and impalpable. The atoms, in Democritus's opinion, were animated; in that of Epicurus, inanimated. How are we to suppose an animated existence from inanimated particles? Says Democritus, "the atoms that give life, must have life."

From these sources, Des Cartes and his followers drew their principles of the indivisibility of matter, and from the same authorities other more modern philosophers have probably derived theirs.

Sir Isaac Newton on this subject, but with his usual diffidence and ability, ventured to conclude that, "God in the beginning formed matter into solid, massy, impenetrable, moveable particles or atoms, of such sizes and figures, and with such other properties, and in such proportion to space, as most conduced to the end for which he formed them; and that these primitive particles being solids, are incomparably harder than any porous bodies compounded of them, even so hard as never to wear or break in pieces; no ordinary power being able to divide what God himself made one in the first creation. While these particles," says he, "continue entire, they may compose bodies of one and the same nature and texture in all ages; but, should they wear away, or break in pieces, the nature of things depending on them may be changed. Water and earth composed of old worn particles and fragments of particles, would not be of the same nature and texture now, with water and earth composed of entire particles in the beginning; and therefore, that nature may be lasting; the changes of corporeal things are to be placed only in the various separations, and new associations of motions of these permanent particles, compound bodies being apt to break, not in the midst of solid particles, but where those particles are laid together and only touch in a few points. These atoms are properly the *minima naturæ*, the least or ultimate particles into which bodies are divisible; and are conceived to be the first rudiments or component parts of all physical magnitude, or the pre-existent and incorruptible matter whereof bodies are formed."

The doctrine of atoms, you will perceive, arises from a supposition, that matter is not divisible *in infinitum*. And hence the Peripatetics are led to deny the reality of atoms. "An atom," say they, "either has parts or it has not; if it has no parts, it is a mere mathematical point; if it has, these parts must also consist of others, and so on to infinity. But, this is to recede from the genuine characters of atoms, which are not esteemed indivisible from their want of parts, (for all physical magnitude must have three dimensions, length, breadth, and thickness, and all extension is divisible); but they are indivisible on account of their solidity, hardness, and impenetrability, which preclude all division, and leave no vacancy for the admission of any foreign force to separate or disunite them. Atoms, as being the first matter, must also be indissoluble, in order to their being incorruptible." Newton, likewise, holds immutability to be requisite, in order to the world's continuing in the same state, and to bodies remaining in the same nature as formerly. The ancients maintained them to be eternal, for what is immutable must be eternal.

Various and very strong objections have been raised to this indivisibility of matter. A real quantity, say its opponents, *infinitely small*, is absurd; for any one part of matter must undoubtedly bear some proportion to another part that may be supposed, and consequently cannot be infinitely less than it. Matter cannot be divided

vided into parts so small but that these are farther divisible. "Hence," says the celebrated Maclaurin, "from our notion of magnitude it follows, that it always consists of parts, and is divisible without end; yet an actual division *in infinitum* is absurd, and an infinitely little quantity is a mere fiction. Philosophers may allow themselves to imagine likewise, infinite orders of infinitely small particles of matter, and suffer themselves to be transported with the idea; but these illusions are not supported by sound geometry, nor are they agreeable to common sense. On similar grounds Priestley combats the idea. "An atom," says he, "by which I mean an *ultimate* component part of any gross body, is necessarily supposed to be perfectly solid, wholly impervious to any other atom; and it also must be round or square, or of some other determinate form: now the parts of such a body as this solid atom must be *divisible*, and therefore have parts." But may it not be asked, whether this be not stepping beyond the bounds of mathematical precision? The ultimate, that is the smallest particle of any body, cannot have parts that are smaller than the smallest; nor is it easily to be conceived how the ultimate particle can be supposed divisible into parts beyond the last. One part of matter, you will allow, cannot be divided but by another; the most subtile of these parts must consequently rest integral; when we get to the utmost link imagination can carry us to, the divisor of the divided must still remain.

The actual divisibility of matter, indeed, is a subject so very intricate and abstracted, that it can only be conjectured upon, and that rationally to a certain degree. How inconceivably minute are the parts of certain bodies! to what an extent are they capable by division! Curious men have followed up the idea, and from calculation have proved, that sixteen ounces of gold, which, if in the form of a cube, would not measure an inch and a quarter, would completely gild a quantity of silver-wire sufficient to circumscribe the whole globe of the earth. But the point seems to be, that if there be no perfectly solid particles, then there can be no matter in the universe. For the farther the division and subdivision of the parts of any body are carried, before you arrive at parts perfectly solid and without pores, the greater the proportion of pores to solid matter in that body. If, therefore, carrying on the division *in infinitum*, you never arrive at parts perfectly solid and without pores, it will follow that all bodies consist of *pores only*, without any matter at all, which is a manifest absurdity. Matter, therefore, if ever it began to have any existence, cannot be infinitely divisible. The supposition would destroy its very existence. The infinite divisibility of matter, under these difficulties, therefore, may very fairly be given up. Not but that at the same time, from the exceedingly minute division of which matter is capable, we may be allowed to call it *indefinitely* divisible. The very notion of an atom is against infinite divisibility; even when we mean no more by atoms, than those small particles, the *figures* of which are proper to the *bodies* composed of them, and which can never be changed so long as that body preserves its nature. Bodies may be very much changed in their form and outward appearance, while their *component elements* suffer no change. What can differ more from itself than the metal of lead in its solid state from the powder of lead? Yet this powder will easily revert to its former condition of solid lead, when mixed over the fire with a portion of the inflammable matter which chymists call phlogiston. Matter is capable of many seeming *transformations*, but no real *transmutations* have ever been discovered. Even plants and animals, at their dissolution, return to the same sort of vegetable earth out of which they arose.*

Next to the indivisibility of matter, the doctrine of *attraction* hath met with the ablest supporters and opponents. Newton hath erroneously been looked upon as its father. I say erroneously, for long before his time, Roberval de Fermat and Pascal thought gravity an attractive power, and inherent in bodies. Hook also had the same notion, and foretold that all the motions of the planets would one day be accounted for on this single principle. The truth is, it was familiarly known and maintained by the ancients. Democritus and Epicurus both held it; and Lucretius, who was well instructed in all their principles, speaks clearly of the true cause of the difference in the descent of bodies. " He believed that a *vacuum* having nothing in it which could retard the movement of bodies, it was necessarily evident that the *lightest* would fall with a quickness equal to the heaviest; for where there is no resistance, bodies must always move in equal times." Newton alone, however, had ideas upon the subject demonstratively clear and explicit.

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* Philosophy of the Elements.

“ With regard to attraction,” says that great man, “ have not the small particles of bodies certain powers, virtues, or forces, by which they act at a distance, not only upon the rays of light for reflecting, refracting, and inflecting them, but also upon one another, for producing a great part of the phænomena of nature? It is well known, that bodies act upon one another by the *attraction of gravity*, magnetism, and electricity; and these instances shew the tenor and course of nature, and make it not improbable but that there may be other attractive powers besides these. *How* these attractions may be performed I do not,” says he, “ here consider. What I call attraction may be performed by *impulse*, or by some *other means* unknown to me. I use the word here to signify only in general, any force by which bodies tend towards each other, whatsoever be the cause. The attractions of gravity, electricity, and magnetism, reach to very sensible distances, and so have been observed by vulgar eyes; and there may be others which reach to such small distances as hitherto to escape observation; and perhaps electrical attraction may reach to such small distances, even without being excited by friction. It seems to me farther,” continues he, “ that these particles of matter have not only a *vis inertiæ*, accompanied with such *passive* laws of motion as naturally result from that force; but also that they are moved by certain *active* principles, such as is that which we call attraction of gravity, and that which causes fermentation, and the cohesion of bodies. These principles," says he, " I consider not as *occult qualities*, supposed to result from the specific forms of things, but as *general laws* of nature, by which the things themselves are formed; this truth appearing to us by phænomena, though their *causes* be not yet discovered. For these are manifest qualities, and their causes only are occult."

" Hypotheses," farther observes Newton, " and the vain imaginations of men, ought not to be admitted in preference to experiments; and as nature is always simple and uniform in her operations, we ought in philosophical researches never to depart from the analogy of it. We no otherways know the *extension* of bodies than by our *senses*; nor do these discover it in *all* bodies; but because we perceive extension in bodies of which our senses can judge, we therefore ascribe it universally to all others also. That abundance of bodies are hard, we learn by experience. Now the hardness of the whole must arise from the hardness of the parts, and hence we rightly conclude, that the small undivided particles of bodies are hard also. That bodies are *impenetrable*, we learn by our senses, and not by reasoning. The bodies which we handle we find impenetrable, and thence infer impenetrability to be a property of all bodies whatsoever. That all bodies are moveable, and endowed with certain powers (which we call their *vis inertiæ*) by which they persevere in motion or rest, we also infer from the like properties observed in the bodies which we have seen. The extension,. hardness, impenetrability, mobility, and *vis inertiæ* of the whole, therefore, result from the extension, hardness, impenetrability, mobility, and *vis inertiæ* of the parts; and hence we conclude the least particle of all bodies to be also extended and hard, and impenetrable and moveable, and endowed with their proper *vis inertiæ*; and this is the *foundation of Philosophy*. Moreover, that the distinct and contiguous parts of bodies may be *separated* one from another, we know from experience; and that the parts which remain undivided may still be distinguished by our minds into less and less, is certain from mathematics; but whether those distinct, and as yet undivided parts, can actually again be divided and separated into parts still less and less by any power in nature, is uncertain. But if it could not be made appear by one experiment, that any hitherto undivided particles should suffer a division, by being broken off from any hard and solid body, we might conclude by the force of this rule, not only that those distinct parts might be separated, but also that they might be divided into parts less and less, *in infinitum*. With respect to *gravity*, if it appears universally by experiments and astronomical observations, that all bodies on the surface of the earth are heavy, or *gravitate* towards the earth, in proportion to the quantity of matter in them; and that the moon gravitates towards the earth according to the quantity of matter contained in it; and on the other hand, that the sea gravitates towards the moon, and that all the planets gravitate towards each other; and also that comets have a like gravitation towards the sun; we must affirm by this rule, that all bodies gravitate towards one another: for the argument, from appearances, in favour of the gravitation of all bodies, will be stronger than for their impenetrability; because we can make no experiments upon the heavenly bodies concerning their impenetrability; however, *I do not affirm gravity to be essential to bodies*. By the natural force of bodies, I understand their *vis inertiæ*, and this is immutable; whereas, gravity may be continually diminished, as the body recedes further and further from the earth."

Attraction, you thus see, is an indefinite term in the system of Newton, applicable to all actions whereby bodies tend towards each other, whether by virtue of their weight, electricity, magnetism, impulse, or any other latent power. Men of science generally reckon four different sorts of attraction, namely, that of cohesion, of electricity, of magnetism, and of gravitation. Attraction of cohesion is peculiar to the component particles of bodies, by virtue of which they are firmly connected and held together. The laws and properties of this attraction are the following. 1. It is discernible and most powerful in corpuscles, or the smallest particles of matter. 2. It is mutually exerted between those particles; or they mutually attract, and are attracted by each other. 3. The sphere of attraction, or extent of this power, is greater in some particles of matter than in others, but very small at the outermost: for, 4. This power is insensible in solid bodies at the least sensible distance, acting as it were only in contact; and therefore, 5, It must be nearly proportional to the quantity of contiguous surfaces; or those parts of the body cohere most strongly, whose touching surfaces are largest. 6. This power must decrease, as the squares of the distances increase; because it must be supposed to issue from each particle in right lined directions. 7. Where the sphere of attraction ends, there a repelling power begins; by which the particles, instead of attracting, repel and fly from each other. 8. By this power the small portions or drops of a fluid conform themselves to a spherical figure. The first and second of these properties are evident from various experiments; as the sudden union of two contiguous drops of mercury, water, &c; the strong adhesion of two leaden balls which touch by polished surfaces; as also of panes of glass and in capillary tubes; the rising of water by the sides of a glass vessel, and into tubes of sand, ashes, sugar, spunge, and all porous substances. The third property is proved by the sticking or adhering of water to substances, which by mercury are left dry. The fourth and fifth properties are evinced by the hyperbolic curve, formed by the superficies of a fluid ascending between glass panes touching each other on one side. The sixth property is evident. The seventh appears from the ascent of a steam, or vapour, from humid or fluid bodies; and the eighth property is manifest by drops of water falling on dust.

From this account of the attraction of cohesion, we have a rational solution of several very curious and surprizing phænomena; as why the parts of bodies adhere and stick so firmly together: why some are hard, others soft; some fixed, others fluid; some elastic, others void of elasticity: all which arise from the different figures of the particles, and the greater or less degree of attraction consequent thereupon. On this principle, we account for the manner in which plants imbibe the nutritive juices by the fibres of the roots; also for the rise of the sap in vegetables, and for the whole economy of vegetation. Hence the rationale of the various secretions of fluids by the glands, and their wonderful circulation through the fine capillary vessels. Hence also the reason of gilding metals; also of melting or fusion by heat. Hence also the exhalation of vapours by the heat of the sun or fire; the aggregation of aqueous particles in the air, forming the drops of rain. We hence see the reason of distillation, filtration, dissolution, digestion, sublimation, precipitation, crystallization, and the other operations of chymistry

mistry and pharmacy. Lastly, It is by the powers of attraction and repulsion that we are, in most instances, to account for those wonderful phænomena of subterraneous ascensions and explosions; of volcanos and earthquakes; of hot springs, damps, and suffocating exhalations in mines.

Notwithstanding these clear and satisfactory data, the cause of the cohesion of matter has extremely perplexed philosophers in all ages. In all their various systems of physics, matter is supposed, originally, to consist of minute divisible, or indivisible atoms; but how, and by what principle these several and distinct corpuscles should be first combined into little systems, and how these little systems should come to persevere in that state of union, is a point not yet determined: a point of the greatest difficulty, and even of the greatest importance of any in physics. J. Bernouilli thinks it owing to the pressure of the atmosphere; others to the figure of the component particles; but the generality, with Sir Isaac Newton, to attraction.

The attraction of gravitation, though reckoned a distinct power from that of cohesion, yet, when well considered, may be found perhaps to differ from it no otherwise, than as a whole from its parts: for the gravity of large bodies may be only the result or aggregate of the particular powers of the constituent particles, which singly act only in contact and in small distances; but with their joint forces, in vast quantities, produce a mighty power, whose efficacy extends to very great distances, proportional to the magnitudes of the bodies.

This doctrine of the attraction of gravity, however ably supported by its illustrious patron, has had weighty difficulties thrown in its way. As all motion, it hath been observed, is in the *direction* of its *cause*, there can be no such thing as a power of attraction; because that supposes a direction in the cause, which is contrary to the direction of the effect, and therefore can never happen consistently with the laws of mechanism. A cause from the earth, can never bring the moon nearer the earth; neither can a cause from the moon bring the waters of the earth nearer to the moon. The cause which is in the direction of a body that moves freely, is an *impelling* cause; and if it be impulse, it is not attraction; if it be attraction, it is not impulse: these principles being of opposite natures, and consequently inconsistent.

In opposition to this, it has been contended, that attraction must be essential to the actual existence of all matter, since no substance can retain any form without it. Gravitation, says its advocates, is unquestionably one of the most simple laws, or principles of motion, which has been observed in the constitution of the universe. This, reply its opponents, is not to be denied. But, is the attraction given to it to be supported on sound and on rational principles? Gravitation from such premises, would seem to imply a law or a power in the active body; attraction in the passive one; and consequently, if the acting body should be made to move by its own gravity or weight, there would be no necessity for an attraction; or if it were to act by attraction, there would be no necessity for gravitation.

How inexplicable soever the cause of this gravity may be, it yet would appear from some of its admirers, who do not even qualify it with a doubt, as their master did, to be a mode of motion, a tendency towards a center. To speak strictly, a relative gravity is a relative quality; for what falls relatively to us, *rises* as relatively to other bodies. Hence, say they, it follows, that all motion in the universe is the effect of gravitation, seeing as we do, that in the universe there is no high, no low, no positive center. This gravity, however, when closely examined, appears rather to be an *accident* to matter, than to be essential to its nature. For certainly all matter has not *weight*. Bodies differing in kind do not preserve a constant relation to each other in respect of weight, when they are in different forms, and differently acted upon. It is the nature of iron to sink in water with a superior specific gravity; but the atoms of iron will be suspended in water. Sulphur will sink in oil; but the oil heated, rarified, and consequently become lighter, the atoms of the sulphur will ascend and be suspended in it. Were gravity essential to matter, all matter would constantly tend, or at least preserve a tendency, towards its proper center. The matter near the earth would all tend towards the earth, and resist every other direction. But, this is by no means agreeable to nature. Here upon earth the *electric fluid*, a sort of matter which seems to fill the world, and is of such consequence that it seems to be the life and soul which invigorates all the rest, will move in every direction indifferently: and fire, when agitated, is rather disposed to ascend in a direction contrary to that of heavy bodies. Absolute gravity, therefore, appears to be a *mutable* thing, and not essential to matter.

The apparently essential properties of matter, as we have already seen, are solidity and extension; for even a particle of water is solid. The first property, solidity, may be perhaps the only essential one of which matter is possessed, and every other may spring from, or be dependent upon it. The other property, and which it is supposed belongs to matter as essentially as solidity, is extension. Reason may resolve these properties both into one; for whatever is extended must have solidity; and whatever is solid must include in it extension. Hence, therefore, it has been supposed incomprehensible, how attraction and repulsion can be necessary to the very being of matter. If they be necessary to the being of matter, they must constitute its essence. Yet attraction, we know, means only the mutual approach of two bodies towards each other. "Per vocem attractionis," says S'Gravesande, "intelligo vim quamcunque quâ dua corpora ad se invicem tendunt." But that cannot constitute the essence or being of bodies, which necessarily *depends* on bodies for its own existence. Material substances, indeed, may by some means or other be separated as well as attracted. No concrete body, for instance, has ever yet been found, which can resist the force of art, much less of nature. Either percussion, tension, trituration,

ration, the action of a dissolving fluid which the chymists call a menstruum, or, above all, the active power of *fire*, will disunite the particles of all concrete bodies. But here it may be demanded, what are the causes of this union of the particles of matter? On this head, as we have before remarked, the ignorance of the wisest manifests itself. If we have recourse to the *æther* of Sir Isaac Newton, which Dr. Cullen supposes may be the cause of the cohesive and repulsive force of bodies; or if we think with Dr. Hales, the late celebrated Haller, and Dr. Macbride, that *air* is the cause of the cohesion and firmness of bodies, which experiments seem to make probable, though yet perhaps not certain; yet we must still inquire into the attractive and repulsive force of this æther or air; for if this æther be *matter*, it must consist of ultimately solid parts, and consequently have a *vis inertiæ*, if it have any existence. Now the parts of this very æther could neither move nor impel any substance, if they were not themselves moved and impelled in the same direction; and thus we shall want a *more subtle* æther for the purpose of moving the grosser; and this more subtle æther will want another still more subtle for the same purpose, and so on, *in infinitum*.

This subject, as I before observed, with all its perplexities, was much agitated by the ancients. Empedocles, according to Diogenes Laertius, held that "there was a sort of friendship by which the elements united one with the other; and a sort of discord by which they kept asunder." From this you see the system of attraction is ancient, though it wanted a Newton to develope it. Love, to whom the ancients attributed the clearing up of chaos, appears to have been nothing else than attraction personified. All the allegories and fables of the ancients on the *chaos*, express nothing more certainly than the attraction and union between analogous or homogeneous substances, whence result the being of the world; whilst repulsion or discord, which they called ΕΡΙΣ, was the cause of its confusion and disorder, and tendency to dissolution. And hence may be conjectured the origin of the dogma of these two principles.

But we will postpone the further consideration of this subject to a time when it will be still perhaps more applicable to our purpose. The principles adopted by the Newtonians were in many instances satisfactory; but they were not so in all. The great philosopher himself was conscious of it. The opinion, that matter is endowed with an attractive and a repulsive power, and that there is a limit where one of these opposite powers ceases, and the other begins to act, is too general and indefinite. The particles of some bodies in nature are certainly attractive of each other, as the particles of metals, earths, &c. but others are repulsive, as air, heat, the electric fluid, &c. Now neither the former lose their attraction, nor the latter their repulsion, except when combined with those bodies which have an attraction towards them, sufficient to *overcome* the natural attractive or repulsive power existing between their own particles. The fact is, the law of attraction, particularly the attraction of cohesion, is very extensive throughout nature. But every law of nature cannot be explained by attraction. On the contrary, repulsion seems to prevail, if possible, more universally than attraction. Electricity, magnetism, the elasticity of metals, and many bodies, particularly the air, all and each of these prove that there is a repelling influence in many parts of matter, and consequently powerfully instruct us not to insist upon either the one or the other exclusively, but to admit the great and admirable agency of both.*

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* Nicholson's Natural Philosophy.

I had hopes, when I had got thus far, to have been enabled to close this long and tedious preliminary investigation, and, for the present at least, to have exonerated you from any thing further on so dry a topic.. But on looking over my letter, I find a few explanatory words may be necessary on that property in nature which, for precision and conveniency, had the appellation given to it by Newton of the *vis inertiæ*. From what has already been said on the subject, you will have thought it not difficult to conceive his meaning. Ingenious men, however, have found fault with the expression. It attributes to body, say they, a power or energy, a force, a something which appears as inconsistent as if it gave the power of light to darkness, or of sight to the blind. For what is power or energy? Is it not a disposition to act, either spontaneously, or in consequence of some impression? In Newton's reasoning there is a state of inactivity endued with action, or a motionless motion. A state of rest can only be a negative to that of motion; and when that ceases, this must always obtain. "*Mobility* in atoms," remarks Mr. Jones,* "is nothing more than a capacity of being moved by any mechanical force applied to them; not that they are endued with any *internal power* of moving them-selves.

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* Philosophy of the Elements.

selves. If we should say, that matter is by nature *inert* and resisting, and indifferent to motion, and then should proceed to give the same matter a disposition to move without some *external force*, we should invest it at once with power and impotence, with sluggishness and activity, which cannot both be predicated of it, without contradiction. The trumpet has a capacity of sounding, but never till it is sounded: of itself it is dead and silent, and, as long as left to itself, must always remain so. Matter, in like manner, hath a capacity of motion, not an ability to move. Let us suppose the present laws of nature all suspended, and all matter annihilated except one single atom; we all confess that this atom can have no inclination to move, but must remain absolutely at rest; and all this from its own *inert nature*. If we introduce another atom, they will both be at rest; for the properties of matter are not changed by having two atoms instead of one. To invest matter with any innate powers or self inclinations to motion, is as contrary to the real nature of matter, as to suppose that all trumpets are born with lips and lungs, and breath of their own: it is to make the world an *animal*, and all the parts of it animated, as the Stoics of old did; it is to resolve all attractions and repulsions into an animation of matter, and suppose them to be the work of certain souls and spirits resident in all natural bodies, and commissioned to act in the several departments of nature."

Notwithstanding these strong objections, and various similar ones, which were started at the very birth of the doctrine, Newton, and many of the deepest philosophers since his time, have maintained, that there is not any thing in physics better settled than this *vis inertiæ* or passive force, by which matter always continues of itself in the state in which it is, and never changes that state, but in proportion to a contrary power acting upon it; so that the very same force which is necessary to give any certain velocity to any certain quantity of matter at rest, is always exactly requisite to reduce the same quantity of matter, from the same degree of velocity, to a state of rest again. "This *vis inertiæ* is always proportional," say they, "to the quantity of matter, whether at rest or in motion, and is never transferred from one body to another. Without this *vis*, the *least force* would give velocity to the *greatest quantity* of matter at rest; and the greatest quantity of matter in velocity of motion, would be stopped by the least force, without any the least shock. So that, properly speaking, all action and re-action, all impulse and resistance, are nothing but this *vis inertiæ* in different circumstances; and, indeed, all force is only a different modification of rest or motion." In regard to the expression itself, fastidiousness alone can find fault with it; and this short explanation will, I hope, be sufficient to shew you that it is neither erroneous nor unphilosophical. Newton having asserted the *inactivity* of matter, it was natural for him to make use of a word not in any respect applicable to activity. The doctrine he had to establish was new, and required a new term. The *vis inertiæ*, therefore, which is a *vis insita*, or innate tendency, struck him.—He applied it to the idea; and it has stood the test of the most enlightened understandings.

In like manner, the occult qualities of the ancients, which Newton has been accused of adhering to, by establishing the probability of the doctrine of attraction, were entirely in the imaginations of his opponents, and not in the principles of his doctrines. By the terms attractive and repulsive forces, he never meant to express *inherent* forces in the molecules of matter. Body, he well knew, cannot act where body is not. But let us suppose the word attraction to be suppressed, can we deny the planetary motion? Or can angry criticism destroy the sublimity of Newton's theory, or the correctness of his calculations?

LETTER XIV.

THE elements are the original component parts of bodies, or they are those into which they are ultimately resolvable. The ancients in general agreed that the elements were four in number, *γη*, *υδωρ*, *πῦρ*, *αερα*; earth, water, fire, and air. Aristotle admitted these four elements, and acknowledged they were sufficient to form all sublunary bodies; yet from the beauty of the firmament he was induced to suspect the heavens to be formed of finer materials; and therefore supposed a sort of fifth element, the quintessence of the other four, for their peculiar construction. But this notion was adopted by very few, and the four elements were, for ages, received as the basis of all natural bodies.—Many modern chymists, however, have disputed the doctrine of the four elements. Notwithstanding which, it does not appear that they have been able to establish any in their stead, which will stand the test of a rigid examination; or concerning which they can generally agree among themselves. The truth is, we cannot always judge of compounds from the principles into which they are *chymically resolvable.* Besides these four primary elements, the ancients held three chymical principles, salt, sulphur, and mercury; and to these our modern chymists have added many others.

On so subtile a subject you will not be surprised that there should have been opinions in every possible direction; and that the number of the elements should have been increased and diminished at pleasure. For instance, the Cartesians admitted only three elements; the first a *materia subtilis*, or fine dust; the second a coarser but round kind; and the third a still more irregular and hooked kind of particles. But the elements or principles generally conjectured at present, and to which bodies are supposed to be reduceable, are, 1. *Water*, or phlegm, which in the chymical analysis rises first in form of vapour. 2. *Air*, which escapes unseen in great quantities from all bodies, so as to constitute half the substance of some of them. 3. *Oil*, which rises afterwards and appears swimming on the surface of the water. 4. *Salt*, which is either volatile, or rises in the still, as that of animal substances; or fixed, as that of vegetables, which is obtained by reducing them to ashes, making a lixivium or ley of these, and afterwards evaporating the moisture; by which means the salts shoot into crystals. 5. *Earth*, or what is called *caput mortuum*, being what remains of the ashes after the salt is extracted; and this is the last element of all bodies which can be no farther altered by any art whatsoever. And hence bodies have been divided into *six classes*, saline, inflammable, metallic, earthy, watery, and aerial. Saline bodies in general excite some kind of sensation. Inflammable bodies are always sensible in a state of inflammation. Metallic bodies act according to gravity, except when heated, and then we are highly sensible of them; but this proceeds from the influence of the element of fire. Earthy bodies in general are inert, and probably constitute the basis of the nutritive matter both of animals and vegetables. Air has a variety of properties, of which elasticity is one of the principal.

To generalize, however, the nature of the elements, and to bring their several properties more familiarly before us, we may venture to conclude, that elementary fire is the principle of activity; earth, the principle of solidity, either from its heretofore supposed impenetrability, or the close union of which its parts are susceptible;

ceptible; water, the proper vehicle which forms the combination of bodies, into which it enters as a constituent part; and air, the fluid in which, as in their proper region, the other elements exercise their movements, and which would seem an essential part in their combination. These elements, which our senses, indeed, never shew us pure, being continually put in motion, one by the other, always acting and re-acting, always combining and separating, attracting and repelling, are sufficient however to explain to us the formation of all the *material beings* we perceive. Their motions without interruption, are alternately cause and effect. They form one vast circle of generations and destructions, of combinations and decompositions.

In the analyzation of these properties, the ancients did not overlook these striking and contrary natures.[*] They soon perceived the passiveness of some, and the activity of others. Thus Ocellus Lucanus, one of the earliest of the Greek writers, and from whom Cicero borrowed the doctrine, says, "two of the elements are passive, and two of them active. Fire and air have the power of motion; water and earth are only capable of receiving the impressions." Of which doctrine, as has been well observed, we have an obvious instance in the body of man, which hath life and motion as long as fire and air maintain their proper stations and perform their proper offices in it; but when they have left it, it becomes nothing but an inactive mass of earth and water, falling quickly into dissolution. All the philosophers, however, of the ancient world were not of this opinion. Thales, among others, looked upon *water* as the sole principle of every thing; others, as Anaximenes, bestowed that property upon *air*; while there were not wanting those, who, like some of our modern naturalists, could find it exclusively in fire. Empedocles, at length, united these opinions, and admitted the elements which we have already enumerated, and which Aristotle adopting from him, handed down to his followers, who transmitted them to the sixteenth century.

The source, whence the discrimination of all these elementary data was derived, was evidently chymistry; an art which, perhaps of all others, has been the most extolled by its admirers, and the most condemned by its opponents. Chymistry, however, was alone equal to an elucidation of the changes caused in bodies by motion. Unassisted by the observation of effects evident to the senses, the human mind was unable to draw within the reach of reason, the vast varieties which were occasioned by this impulsive power. To this science therefore, which comprehends all those particular properties of bodies which are ascertained by the assistance of heat or the application of other bodies, and include all that infinite variety of new appearances and particular properties, which are the result of combination or separation, we are greatly indebted. Many of the ancients conjectured, and many of the moderns had glimpses of the truth ; but, years alone have been able to ascertain and explain it.

Fire, the element with which we shall begin, is defined, an ever acting, penetrating fluid, endowed with a continual motion, and tending always to increase; never capable of being seized, or examined as to its properties; and from that impossibility, it is left to us to judge of it merely in its effects. Boerhaave divides these effects into three, light, heat, and rarefaction. Light, as discovered by Newton, is to be decomposed into seven different rays: red, a primitive simple colour; orange, a colour composed of red and yellow; yellow, a primitive simple colour;

green, composed of yellow and blue; blue, primitive and simple; indigo, composed of blue and violet; violet, primitive and simple.—And these, after the opinion of the ancients, he proved to exist from their relative capacities, and their power to retain the solar rays: for, were colour in the atoms themselves, says Lucretius, it would be as intransmutable as they are; and so the things consisting of atoms, that are of no colour, could not change in that respect, and appear with colour; whereas, we observe the contrary happens, for the sea foaming, looks white, it being otherwise of a green colour, which doubtless, if it were in it by reason of green atoms, could not be changed into a white colour. Light comes from the sun to the earth in little more than seven minutes. It is transmitted to our eyes by a peculiar fluid, which occupies the interval between us and visible bodies. But, whether it comes directly from the sun, by successive emissions or eradiations, or whether it be a peculiar fluid distributed through space, and put in action by the sun's rotatory motion, or by any other cause, is not at present essential to our inquiry. All natural bodies may be considered as prisms, which decompose, or rather divide the light. Some reflect the rays without producing any change, and those are white; others absorb them all, and cause absolute blackness. Light is not merely a physical substance; its effects are strikingly evident in all the phænomena of nature, particularly in the animal and vegetable kingdoms.—Organization, sensation, spontaneous motion, and life, exist only at the surface of the earth, and in places exposed to light. Without light, nature would be lifeless, inanimate and dead: a benevolent God, by producing light, has spread organization, sensation, and thought, over the surface of the earth.

Heat penetrates all bodies without exception, though it does not render them more elastic than they were when cold. It tends always to preserve an equilibrium. Its weight is not known, for nothing proves that a body heated is heavier than when it was cold. It quits a substance by slow degrees. It dilates the most part of minerals; and when strong, contracts organic bodies. All these properties, however, did not, it was supposed, demonstrate the existence of body, and therefore it was thought, that heat was a modification, like motion. Bacon believed it to be the collision of the last molecules of bodies the one on the other, and his opinion was adopted by many. As no substance however rarefied by heat acquires weight, but on the contrary loses it, it was likewise imagined that rarefaction was simply the putting asunder the parts of a warm body, the pores of which were increased in such a manner, as to have greater voids, and less solid parts, in a given space, than they had before.

The power of fire is so great, its effects so extensive, and the manner of its acting so wonderful, that some of the wisest nations of old reverenced and worshipped it as the Supreme Deity. Some of the chymists, also, after they had discovered its surprising operations, suspected it to be an *uncreated being*. The Vesta of the Roman was no other than the element of fire; the *Eςια* of the Greeks, which the best philologists derive from the *Esh* of the Hebrews.* The Apis and Serapis of the Egyptians, besides similar symbolical representations among the Chaldæans and Phænicians, may be referred to the same original. Fire, being the purest body in nature, its worshippers supposed that it ought to be honoured with the purest kind of devotion; on which account, the female votaries of this deity were bound to inviolable chastity. Hippocrates without reserve attributes to this element *mind* and *understanding*, Εν τουτῳ ψυχη νοος φρονεσις. The Stoics held the divinity of fire. By the fabulous history of Vulcan, the terrestrial and subterraneous fire is to be understood, according to chymical mythologists, as being the fabrication of all those mineral exhalations, which mount up into the sky, and furnish Jupiter with the materials for his thunder and lightning. Fire was even by some supposed to be Jupiter himself.

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*. Philosophy of the Elements.

Fire is generally divided into three kinds or species, viz. celestial, subterraneous and culinary; or more properly solar, culinary, and elementary. The solar is that fire which resides in the orb of the sun as its reservoir, and proceeds from it in the form of light.* The culinary is that fire which is kindled upon earth by any artificial means, and burns in any sort of fuel. The elementary is that subtile fluid, which resides constantly in all gross bodies, and is not necessarily distinguished by its heat, as culinary fire; nor by its light, as the solar or siderial fire; but is known by other effects, even in a cold invisible state. These three are one and the same fluid; for they have the same properties, and the same effects. The solar fire will burn in fuel, and act on solid matter with greater effect, than the most violent fire of a furnace: the culinary fire will promote vegetation and ripen fruits, as the sun does: the elementary will light a candle, and fire gun-powder, as the culinary; will afford a spectrum of the seven primordial colours, in common with the solar rays, or the light of an ordinary fire; and will throw metals into fusion, with a melting, scorching heat. They are, however, agitated with a different sort of motion. The solar matter, or light, moves in right lines; the culinary vibrates and tends naturally upwards; the elementary presses in with a shock to restore an equilibrium, and is diffused in all directions. But, still they are radically the same. The solar fire, which penetrates the opaque body of the earth, is there dissipated, and becomes elementary: the elementary, agitated by any violent motion or attrition, and communicated to any proper combustible matter, becomes culinary; and the culinary, when cold and extinct, becomes elementary again.

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* Philosophy of the Elements.

When these and some other points came to be understood, it was readily perceived that the spirituality of fire was to be given up, and that it was to be considered as a corporeal substance; for as it can drive out matter from any given space, that which can expel other bodies, and take place of them, must itself be a body. It may be seen to pass through a liquor shooting in subtile streams. It therefore is *material* as air is, which in liquor is seen in bubbles. Boerhaave brings it as an experiment, to prove that fire is a true corporeal substance, that the rays of the sun, from a very powerful burning glass, directed to the extremity of a magnetic needle, gave *motion* to it, as a stroke or a blast would have done. But, if we want any evidence that fire can affect bodies with a true corporeal percussion, we have nothing to do but to feel the shock of it in electricity.

One principal difficulty concerning the nature of fire, is to determine, whether it be originally such, formed thus by the Creator himself at the beginning of things; or whether it be mechanically producible from other bodies, by inducing some alterations in the particles thereof? The former opinion is maintained by Homberg, Boerhaave, the younger Lemery, S'Gravesande: the latter is chiefly supported by our English philosophers, Bacon, Boyle, and Newton. But, we will not here enter into so endless a field of discussion. The one party held fire to be coeval with bodies; and the other, that to produce heat in a body, nothing was required but to excite a certain motion in its parts. A still greater question, if possible, hath since indeed arisen; and as it even at this moment admits of controversy, we shall not misemploy our time in giving it a little of our attention.

It is of small importance, when or by whom the doctrine, that light is not the same substance with heat, was started. The philosophers of the continent had it many years ago, and among others, L'Abbe Pluche and Boerhaave, who insisted, that the body of fire was an element quite different from the body of light; that fire was not emitted from the sun by projection, but resides all around us; that it was equally dispersed in the air and in all bodies; that it betrays its presence in proportion as it is disturbed and pressed; that it remains there constantly the same; that it is both ingenerable and indestructible; that it can neither generate any new fire, nor be produced where it was not; that it may be laid hold of; that it can push, and divide other bodies, that it may not act diversely with them; but that it can convert nothing into its own nature, for that otherwise every thing would have been changed into fire, since the six thousand years that fire has been burning. The celebrated Bergman leaned also to the same opinion. " I know," says he, " that many philosophers of the first rank are of opinion, that the phænomena of heat are to be explained upon the supposition of *intestine motion* in bodies; but upon considering the whole attentively, I am firmly persuaded that heat arises from the action of a *distinct* and peculiar substance, which is distributed through the whole corporeal world, and that in a two-fold state; for, first, we consider this matter as *free*, when, in form of an elastic fluid, continually tending to an equilibrium, it pervades all bodies, dense as well as rare. This, in proportion to its quantity, excites different degrees of heat in animals, dilates and disposes all bodies to *fluidity* according to certain circumstances. Thus platina, in order to be fused, requires to be very highly concentrated; other metals less so; and mercury, a quantity so small, that a sufficiency is almost always present in the atmosphere; I say almost always, for some late observations in Siberia shew, that there mercury has been sometimes congealed by *natural cold*. Whether there can exist any such state as that of perfect *privation of heat*, or absolute cold, is yet unknown. In such a state, (supposing any such to exist) if I mistake not," continues Bergman, " the *aerial acid* itself must be congealed, as fluidity appears to depend entirely upon heat. It is necessary, however, that phlogiston, the matter of heat, and fire, should be carefully distinguished: *phlogiston*, combined with pure air in a certain proportion, constitutes the *matter of heat*; *fire* is the action, by which a body is *deprived* of phlogiston by means of pure air, with such vehemence as to generate not only heat but *flame*. Fire, therefore, should rather be called the *matter of heat*; for in the action of heat, when increased to a certain degree, it soon passes away after the consumption of the fuel; but the heat continues though it becomes rarified, and is distributed among other bodies. There is always heat in fire, but all heat is not sufficient for exciting fire. Thence we conclude, that every body has a determinate specific heat, which, however, appears from experiment to vary with the state of the body. In the solid state, it contains least; in the liquid, more; and in the fluid, in which there is the weakest cohesion, it has the most specific fire."

Many other objections have been advanced against the received doctrine of light and heat. Mons. De Lisle in particular contended, that though the solar rays do not produce heat by their friction against the parts of the aerial fluid, yet they form combinations with certain parts of that fluid, which have no affinity to them; and that a concentrated acid in these rays, uniting with the aqueous particles of the air, produces, as a primary cause, the heat, the principle of which was sought for in the direct influence of the sun, and other causes. Wherefore, the solar rays, if they did not meet with the aqueous particles of the air, would arrive at the earth, *without* warmth or energy, as they do at the tops of mountains."

You will ask me here, however, what is this concentrated acid? Monsieur Sage will tell you, there is a primitive, igneous, phosphoric acid, the universal or elementary acid, and of which all the other acids are but modifications. When circulating in animals, it is the animal acid; when in vegetables, the vegetable acid; and this latter, modified by the various fermentations, produces the acid of wine, æthereal acid, acid of tartar, and even the acid of vinegar, after having been anew modified by the acetous fermentation. The vitriolic acid, says he, is a modification of the same phosphoric acid. The aerial acid, or fixed air, is an alteration of which this universal acid is susceptible. The vitriolic acid, modified by a small portion of the inflammable principle, gives the volatile sulphurous acid; modified by the odorous principle which proceeds from bodies in a putrescent state, it gives the nitrous acid; and when these bodies are only at the commencement of putrescency, the marine acid. This phosphoric, or universal acid, in various manners, and in various combinations, is diffused through nature. It enters into the formation of light and fire; it is one of the essential and integral parts of air. There is no animal, or vegetable, that is not possessed of it. It enters into the composition of calcareous earth; of phosphoric spars; of basaltæ; of alkalis; and of the pure dephlogisticated air, by which we breathe and exist. It is not to be produced, it cannot be decomposed, and is the heaviest of all acids.

Neither fire, nor air, nor earth, nor water, have always been allowed to be primitive, or simple indestructible elements. They have, on the contrary, been said to depend on the union of certain more subtile principles, which are to be disunited and recomposed at pleasure. But, what these more subtile principles are, nobody can tell.

Among the ablest defenders, however, of the hypothesis endeavoured to be destroyed by these and such other acute and ingenious modes of reasoning, hath been the present learned professor of Geneva, Monsieur De Saussure. In his late instructive writings on the Alps, he asks what is the cause, why *cold* reigns so powerfully on mountains? " The great geometrician Lambert," says he, " informs us, that heat mounts in air, without interruption. That which the earth receives from the sun during the course of a year, strikes upwards and spreads itself, as the earth stands in continual need of new heat, lest it should become too cold. As much then as the *ascension* of heat depends upon its *levity*, so much does its quickness increase as it ascends. Hence it is that the particles of fire fly distant from each other, as they mount upwards; and consequently, that their *density*, and of course their heat, *diminish* in the superior regions of the atmosphere." De Luc, in this, agrees with Lambert, that the igneous fluid is more rare in the higher regions of the atmosphere; but his reasons are in perfect contradiction to Lambert. The geometrician of Berlin conceived the fire to become *rarified* by the action of the weight of the air. De Luc, on the contrary, contends, that it becomes condensed in the lower regions of the atmosphere by its own *specific weight*. Lambert considered fire as a fluid in motion, which rarified according to the acceleration of its ascension. De Luc compares it to a close fluid, the particles of which are condensed from a reciprocal pressure. Finally, on the question of the *identity of fire and light*, which Mons. Lambert did not venture to resolve upon, but to the affirmative of which, it is very evident, he leaned, De Luc boldly decides in the *negative*; and holds it as certain, that light is a body incapable of warming another body of its own accord; but that put into motion, the *igneous fluid which it contains* then acts, and with the strongest power near the surface of the earth, because, as an elastic and weighty fluid, it is more condensed there, than in a more elevated part of the atmosphere.

" For myself," says De Saussure, " I freely confess, notwithstanding the authority of such celebrated philosophers, I neither can look upon fire as a fluid, so entirely free and independent as to elevate itself with such rapidity by its specific levity, or to condense itself by its specific gravity. It appears to me, that the more the phænomena of that subtile matter is inquired into, the more a man must be convinced that it is connected with all bodies by so great an affinity, that all its motions are determined, or most powerfully modified by that affinity. An ignited body plunged in air, indeed, gives a greater heat *above* than it does below, in consequence of the axiom, that heat ascends. But, this effect is undoubtedly owing either to the levity of the fluid which constitutes the flame, or to the levity of the air dilated by the heat, and not to the specific levity of the igneous fluid itself. Not but that I regard the igneous fluid as incomparably more light than air; at the same time, I do not believe it enjoys a freedom so complete in our atmosphere, as to ascend in virtue of its own specific levity."—The celebrated Monsieur Bouguer, in treating of his voyage to Peru, says, "One has reason, in the explanation of the cold which reigns on the tops of high mountains, to insist on the *short continuance* of the action of the sun, which prevents each of their faces from being struck. An *horizontal plain*, when the heavens are pure, is subject in open day to the *perpendicular* action of the rays of the sun, and without any thing to diminish their force; instead of which, a ground greatly inclined, or the sides of a high pointed rock, cannot be struck but *obliquely*. But, let us suppose for a moment an *insulated* point in the midst of the high regions of the atmosphere, and setting aside the idea of all mountains, suppose it as the clouds which float in the air. The more a medium is diaphanous, the less of heat must it receive from the direct action of the sun. The facility with which a very transparent body gives passage to the rays, shews it is with difficulty the minute particles are struck against each other.—In fact, what impression is to be received from it, when in its passage it scarcely meets with any obstacle? In the higher regions, the air is subtile and transparent. In the lower, the air being denser, is heated by contact, or by the neighbourhood of bodies more dense. The lowest bed of the atmosphere by this means contracts daily a very considerable heat, and increases in the ratio of its density. But, one readily sees, it is not the same thing, at a league and a half, and at two leagues from the surface of the earth, although the light which passes is a little more vivid. The air and wind must, therefore, in such situations be always extremely cold; and the more the points are elevated, the more penetrating must be the cold."

"A fact well known," says De Saussure, "and which proves strongly to my mind, that the action of the solar rays, considered in themselves, and independent of all exterior causes of cold, is as great on the tops of mountains as in the level country, is, that the *force* of a *lens* is the same at all heights. I am thoroughly convinced, therefore, with Bouguer," continues he, "that the principal reason of the cold which reigns on the tops of mountains, particularly those insulated, is, that they are always surrounded and cooled by an air that is invariably cold; and that that air is cold, because it cannot be greatly heated, neither by the rays of the sun, in consequence of its *transparency*, or by the surface of the earth, on account of its distance from the surface.

But, philosophers, not satisfied with the effect, are even divided about the nature of light. Some think it the same as the element of *fire*, in the state of its greatest purity; others look upon it as of a totally different nature, incapable by itself of heating; and that it has no other power, than that of giving motion to the igneous fluid which produces heat. Yet, all agree, that light does not excite heat in bodies, but in proportion as it is absorbed by them; and different bodies, we know, absorb light in greater or less quantities. For instance, Dr. Franklin having exposed two small pieces of cloth, of the same texture, but of different colours, upon the surface of the snow, and to the rays of the sun, he perceived, a few hours afterwards, that the red cloth was buried in the snow, while the other, which was white, had not suffered any depression. Mons. de Saussure also observes, that the peasants of the mountains of Switzerland are careful to spread a black earth over the surface of grounds covered with snow, when they are desirous of melting it, to sow their seed. So likewise children burn a black hat in the focus of a small lens, which would scarcely heat a white one.

Thus the denser air is, the more it is charged with vapour, and the hotter it is. Are not then the *reverberation* of the rays of the sun, from the surface of the earth; the *reflection* from the denser parts of the atmosphere; and the *superficial heat* of the globe itself, the real causes which render it warmer on plains than on mountains?

" The influence of the surface of the earth on the temperature of different places," continues De Saussure, " proves strongly, that it is to reverberation, and the communication of the internal heat, that the greatest part of the heat of our plains is owing. Why, under the torrid zone, have the little islands a temperature always supportable, while the middle of continents, situated in the same latitude, is tormented by the most violent heat, if it were not that the sea re-

receives the sun deeper, and returns less of its heat into the air than the earth? Why is it that *cultivated* countries have better air than others, if it be not that cultivated lands receive and return more of the rays of the sun than forests? Why, in the center of Europe, does one feel a considerable augmentation of heat at the period immediately following the harvest, if it be not that the corn is not capable of reverberating into the air as much heat as the earth itself? At nineteen hundred toises above the level of the sea, in ascending Mont Blanc, and without any snow about me, which could reverberate, I found it insupportably hot. Whence is this? To me it appears to arise from the great sensibility of the human frame in such an elevation, particularly as the thermometer did not accord with the sensation. The considerable diminution in the pressure of the atmosphere on one's body at such a height, must unavoidably produce a relaxation in the whole of the vascular system; and hence it follows, that the direct heat of the sun, which tends to dilate the liquids inclosed in these vessels, and even to disengage the elastic fluids, must of course produce a great effect on the tops of mountains; and the same may be said with respect to the difficulty of breathing, and the prodigious fatigue which we perceive as we advance in elevation."

The ingenuity, and the strong grounds of demonstrative evidence which this reasoning apparently possesses, would have been sufficient, you would have thought, to have precluded all further controversy upon the subject. It had even great antiquity to support it, for Aristotle explained the reason why the air near the earth was more heated than in higher situations; and Seneca, after him, assigned the same reason, the reflection of the solar rays from the surface of the ground, "quod radii solis a terra resiliunt et in se recurrunt. Horum duplicatio proxima quæque a terris calefacit, qeuæ ideo plus habent teporis, quia solem bis sentiunt." But De Luc felt otherwise. The causes to him seemed inadequate to the phænomena. "M. De Saussure," says he, "contends that the rays of the sun are *fire*, and that in passing through a rare and pure air they heat it but little; and that they produce greater and greater heat in proportion as the air is more dense and more loaded with vapours. Now this very circumstance may be considered, in my opinion, as a proof that light is *not* fire; for fire would follow a very different progression. If a globe of metal, very hot but not luminous, was suspended in the upper part of the atmosphere, it would heat the parts nearest to it most, and the earth would receive no greater heat than that of the stratum of air contiguous to it. Mons. De Saussure endeavours to prove likewise, that the greater heat of the air on the plains is owing to the heat communicated to it by the earth. But from the very curious experiments of Mons. Picket, it is evident, that in the night, to the height of fifty feet, which is as far as his experiments went, there is no stratum of air *less hot* than that which rests immediately on the ground. Thus it appears conclusive to me, that the greater degree of heat which the sun's rays produce in the lower part of the atmosphere, is owing not to the greater density of the air, but to the greater quantity of *watery vapours* it contains. For let us recollect, that it is not that part of the day, in which the sun produces greatest heat in the lower strata, that the watery vapours are diminished there; yet without reaching the upper ones, it is natural to conclude, that the two effects are connected with the same cause, namely, the transformation of vapours into air by the solar action. And as in this case a sufficiency of fire must be formed, not only for supplying what is necessary to the constitution of the new air, but likewise for producing an increase in the quantity of free fire, it will follow, that the water which then disappears, contained the matter of fire, and that the ſun's rays, in producing fire with that matter, produced alſo the ſubſtance which diſtinguiſhes the nitrous acid.

De Luc likewiſe ſupported his opinion, by proving, "that when there was a more than ordinary quantity of vapour in the atmoſphere, but without clouds, the rays of the ſun were more warm than when it was ſerene. As exhalations of all kinds, ſays he, are leſs conſiderable in winter than in ſummer, this deficiency may in a great meaſure account for the ſmall degree of heat in winter. And this enables me to aſſign the reaſon why there ſhould be ſo great a difference in the cold of water in countries almoſt exactly in the ſame latitude, but varying in the nature of their atmoſphere. For example, it is well known the winters in England are leſs ſevere than thoſe on the continent in the ſame latitude, and of an equally low ſituation. The reaſon is clear; England being an iſland, is always covered with *vapours* which ariſe from the ſea, and conſequently the rays of the ſun can cauſe more heat in England than in a drier and clearer ſky."

It will be unneceſſary to trouble you with any thing more of the controverſy which has been, and is still carrying on between these celebrated philosophers of the country where you now are. It is a curious subject, but liable to endless discussion. For my own part, I must honestly confess my full assent to the doctrine, that the solar light is positive heat. The conclusions drawn from M. Picket's experiments of the stratum of air next to the earth being coldest at night, are rather ingenious, I think, than convincing. Aqueous vapours will certainly multiply, and consequently increase the quantity of heat; but in order to do so, they must be acted upon by heat. Now is it not to be presumed, that during the coldness of the night, that is, during the absence of the sun, the particles of fire would rush from the surface of the earth, in successive progression from the stratum of air immediately adjoining to the surface, to supply the general deficiency occasioned in the higher regions by the absence of the solar influence? Fire, it is well known, is a fluid that endeavours to expand itself on all sides, and, like other fluids, to maintain its *equilibrium*. In the expansion of air, its capacity for heat is enlarged. Elastic fluids, while they expand, absorb heat from all bodies in their vicinity, so as to produce cold in them. Thus, when bereft of heat from the sun, they will of course absorb and exhaust from the earth the whole of the replenishment, which it received in the day; and thus, consequently, the air nearest the ground in the night will be colder than at an elevation of many feet in the atmosphere.

"As the *earth*," says Kirwan, "is the chief source of heat in the atmosphere that surrounds it, distance from the earth is the source of cold; or in other words, the grearest cold must prevail in the highest regions of the atmosphere; and so much the greater, as clear, unclouded air seems to receive no heat whatsoever from the rays of the sun, whether direct or reflected. Thus, if the focus of the most powerful burning glass be directed on *mere air*, it does not produce the smallest degree of heat; and the reason is, because the air being transparent, affords a free passage to the rays of light, which act as *fire* only when *confined* within the minutest interstices of bodies; as it is then, and then only, that they *counteract* the *attractive power* of the particles of matter; in which action and re-action *heat consists*. The next general source of cold is *evaporation*; for the attraction of the particles of liquids decreases, as their points of contact diminish, and thereby their capacity for receiving the matter of heat (which is the same as light) increases. By this increased capacity; the matter of heat or fire contained in the neighbouring bodies, which, like all other fluids, flows when it finds least resistance, is determined to flow towards the vapour; and consequently those bodies are cooled, though the vapour is not heated, because the re-action of its particles is barely equal to that which it had before its capacity was increased. Even in our own persons we can prove, that when the body perspires strongly, it is less heated than surrounding bodies, and that perspiration always produces a certain degree of coldness. Almost all fevers end in perspirations, which, beside the advantage of expelling the morbific matter, possess, likewise, that of carrying off the matter of heat, and restoring the body to its common temperature. In fact, all gaseous substances are maintained in the aeriform state merely by the heat which is combined with them.

The heated state of bodies most evidently consists of a subtile vibratory motion of their parts. For the particles which constitute light, being thrown from luminous bodies with such amazing velocity, it is clear, whatever be the cause of such projection, the re-action consequent upon it must be considerable. But what is this light, I may be asked again? * "It must be," an anti-Newtonian would say, "either a luminous body of itself, or it must issue out of, and proceed from some other body." Now the latter case is improbable, and from this simple experiment. Suppose a bright and burning flame, of one inch diameter, be placed upon an eminence, it will send its light around it for the space of three miles, which makes one hundred and thirteen cubical miles. Now that this small body should incessantly emit such a prodigious quantity of particles as to *fill* this space, appears incredible, even upon the supposition of the *infinite divisibility* of matter. Is it not more natural to suppose, that objects become *visible*, by those particles of light which *intervene* between our eyes and the object, being properly *excited* and put in motion?

This reasoning, however plausible, and though bordering upon that of the great Des Cartes, is yet, perhaps, erroneous. Light, we may suppose to be certain inconceivably small particles of matter, of different magnitudes, which are emitted or reflected from every point in the surface of a luminous body, in *right lines*, and in

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* Nicholson's Natural Philosophy.

all directions, with an unparallelled velocity, and whose power and intensity decrease as the squares of the distances increase. Were it always diffused, and always existing in the air, we should see as clearly in the *night* as we do in the day, because the sun below the horizon would certainly impel the globules on all sides, and the impression would equally affect our eyes. "The *colour*, however, you must acknowledge," say again the anti-Newtonians, "has assuredly a connection with the degree of heat. Nay, so certain is this, that with those who are concerned in certain chymical processes, the colour is the criterion of the degree of heat. Thus they know, that the body or matter they are operating upon, when just beginning to glow, is at one degree of heat; when of a cherry red, a higher; when orange, still higher; and when white, greatest of all." To this I can only answer, on general principles, and in words which have been often made use of. The colours of natural bodies depend upon the thickness and density of their component parts, and consequently the minutest *changes* in either of these qualities will make very considerable changes in the colour. But there is, besides this, great *uncertainty* of colour, according as the heat varies; and this is in fact much felt and complained of. Crystals of quickſilver in *aqua fortis* are white, yellow, or red, according to the degree of heat to which they have been expoſed; whilſt, on the other hand, the ſame quickſilver, corroded into a saline maſs by *oil of vitriol*, remains perfectly white in all degrees of heat.*

Notwithſtanding the apparently irrefragable truth of ſome of theſe poſitions, the controverſy is ſtill ſaid to be undecided. "You hold;" ſay the oppoſers of the Newtonian doctrine, "that the particles of light are emitted from the ſurface of luminous bodies. So far we will grant you. But, in return, you ſurely can have no objection to allow us, that in conſequence of ſuch emiſſion, the ſubſtances of ſuch luminous bodies muſt be gradually diſſipated? Let us have the permiſſion, therefore, to aſk you, if ſuch be the caſe, how you can account for the conſtant and immenſe conſumption of the ſolar light, without the volume of its orb being diminiſhed?"

Here is indeed a difficulty, which has long tormented and perplexed the profoundeſt of our philoſophers. The analogy of nature, however, preſents itſelf in a ſtriking manner to

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* Nicholſon's Natural Philoſophy.

us, and, at least, allows us to conjecture that, whatever the particular mode may be, there yet unquestionably must be some mode of bringing the sun's own matter back to him in circulation; otherwise his source must undeniably have been exhausted thousands of years ago. Circulation, then,* would seem the only principle upon which the phænomenon can best be accounted for. Circulation, indeed, at once solves the difficulty, and that in an intelligible manner. First, it accords with the progressive motion of light, the source of which would be inexhaustible, because there could be no exhaustion, where there was a supposed circulation. Secondly, it agrees best with that analogy, which is so remarkable in the other departments of nature. The blood, for instance, has a progressive motion in the bodies of all animals; water has a progressive motion in the earth and seas; wind has a progressive motion in the atmosphere; and all these are kept up by the grand principle of circulation. The blood returns into its own source; the water returns to the ocean whence it came; the air circulates with contrary currents in the atmosphere; the equatorial and polar parts always supply each other reciprocally, to restore the *equilibrium*: so that if the matter of the sun returns into itself, there is nothing singular in the case; and that philosophy is certainly the most admissible, which creates the fewest principles, and explains nature in such a way as to make it consistent with itself. Thirdly, the fire of the heavens is thus understood to burn on the same principles as the fires of the earth, with a constant supply of elementary matter. And, lastly, there is this further advantage, the greatest indeed of all, the operation of a double *perpetual* motion in the system, the first and greatest of all *secondary causes*, accommodated in every respect to account for the revolutions of the heavenly bodies, which no other hypothesis ever did or ever could be able to do with any appearance of consistency and probability. "Hoc est ergo sol in æthere, quod in animali cor."* "The heart of animals," said Harvey, "is the foundation of life, the chief ruler of all things in the animal system, the sun of the microcosm, from which flows all its strength and vigour."

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* Philosophy of the Elements.

But, let us ask, as the followers of Newton believe that the rays of the sun not only come to us but extend to the limits of the solar system, where is the difficulty in believing that

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* Macrobius.

they return to the source whence they have issued? Is a reflux of light a more incomprehensible operation, than a flux of light? Newton says, "Light consists in the emission of the particles of luminous bodies; thus the sun darts from its surface, and from every part at the same time, those molecules of its substance which come to us in seven or eight minutes." And in this he followed Epicurus and Lucretius, who supposed light to be an emanation from luminous bodies; as odour is an emanation from odorous bodies. Newton, however, followed the idea up to demonstration, and proved it, as I have already said, from the seven distinct colours, or corpuscles of different densities and different velocities, which this solar matter affords, and which, all blended together, give the luminous body we call light.

As you have above seen, however, Newton's theory has by many great men been looked upon as objectionable. Some, such as Euler, would substitute an independent elastic fluid, universally compressed and agitated by the sun: others would have an æther, universally diffused, and rendered luminous, by a vibration occasioned by the planetary motion. Neither of these opinions, however, agree so well with the simple propagation of light. Light, we all know, is projected in straight lines; whereas, an elastic fluid, pressed upon, or an æther strongly vibrated, would cause an undulatory diffusion of the luminous particles. But, it is said, the parts of a sonorous body are not diffused in the sound which is carried through the air, and why should it be otherwise with a luminous body?

To this, I think, it may be answered, that sound is not material, as its vehicle air is; but that light is material, that is, a substance. Sound does not decrease the bulk of the body whence it issues, but light, when joined with heat, always does. Moreover, odour is supposed to consist of odorous particles emitted from an odorous body; and why may not light be supposed to consist of luminous particles emitted from a luminous body? In regard to fire, indeed, every philosopher, since the revival of science, from Bacon, Boyle and Des Cartes, to Boerhaave, Stahl, Lavoisier, and an endles list, each has had a clear, but a different opinion. Some will have this great agent of all our phænomena an integral substance, the same as light, but altogether unaccountable from being invisible, as well as visible. Others will deduce it from the rapid motion of a certain fluid which, they hold, the universe to be filled with, and by which, without any propagation of rays, the world is illuminated at once.

This wonderful cause, or this wonderful effect, whichever it may be, flies, it must be confessed, from every research. The most violent heat does not manifest itself by any luminous appearance; nor, in some instances, does the most brilliant lucidity afford any heat. These contradistinctions would, therefore, seem to indicate two contrary elements, or at least distinct modifications of the same substance; and might further lead one to believe, that the action of light, to cause heat, is determined by the integrity of that light. Fire is in every substance in nature, light is not so. Fire proceeds in every direction, light always in straight lines. The principle of heat in animals, in vegetables, in fluids, and even in solids, is in action without being visible; but, phosphoric bodies, which are to be met with in mineral, as well as in animal and vegetable substances, are luminous and visible, and yet yield no heat. This, however, does not go to prove that heat is not joined with light in the solar emissions, any more, than because these emissions scarcely affect a diaphanous body, they are also incapable of affecting an opaque one, in which they fix, and which they consequently heat. Does not the burning mirror, by concentrating the solar rays into one focus, give an astonishing degree of heat? And as that heat burns intensely, can it be called any thing but fire?

But, where is the sound philosophy, (I hope I may be pardoned the question) of reducing every thing to one, and one only cause? There are luminous bodies without heat; there are heated bodies without lucidity. Is it not, therefore, allowed us to believe, that heat and light may be blended in the solar ray, as fragrance and colour are in the rose? Light, heat, and flame, may be modifications, but they do not alter the nature of a first substance. Whether motion be the cause of fire, or fire the cause of motion, the phænomena rest still the same. If the sun do not give us immediate heat from its own substance, it is the cause of giving us immediate heat from some other substance. A positive emission of particles, or a positive action on an universal medium, comes to one and the same point. Our bleak north east winds, which, in their violence are reflected so as to cause powerful collisions, never generate heat. But, the sun we feel to be the source of heat, the nearer we advance, or the more we recede from the equator, and this in the ratio of the reflection of its rays.

The phænomena of light and of heat, however, may be distinct from the phænomenon of terrestrial burning. The element of fire, we know, is every where: it is in the earth we tread upon; it is in the air we breathe; it is in the aliments that nourish us; no part of nature is without it. But, it has long been ascertained, that combustion will not take place unless it be nourished by air; that a given quantity of air, in which a body is left to burn, will admit of combustion no longer than it is able to feed it with a portion of itself. Thus, in the beginning a body supplied with a certain quantity of air, burns with violence; but, no sooner is the surrounding air decomposed or vitiated, than the fire is extinguished, and combustion is at an end. On examination, the volume of this air is found diminished, and its nature so entirely changed, as to have become a totally different fluid. The vital, or dephlogisticated parts of it, and which alone administer to combustion, are found expended: and hence that doctrine, that burning is caused by the faculty which some substances have to decompose vital air, from the general mass of the atmosphere; and that heat, flame, and light, are proportioned to the rapidity of this decomposition—for that slow decompositions scarcely give light or heat.

So far as these principles regard common combustion, they may be allowed to militate against the phlogistic hypothesis of Stahl. But, what are the properties these certain substances possess, which enable them to decompose this vital air? Are they such, as that it would be improper to reduce them into one, and call them all by the name of the inflammable principle, or the principle of fire *sui generis*? Can vital air, without the agency of these properties, cause heat, light, or combustion? In the innermost recesses of nature, in her coldest, and in her darkest abodes, there is, we know, a penetrating, subtile fluid, which causes animation, vegetation, fluidity, evaporation, and, in a word, all the phænomena of this our little globe. Is this a distinct substance? Is this a matter different from vital air? Vital air does not operate to the expansion of metals; nor does the absence of vital air to their contraction. Vital air does not give fluidity to ice, nor does the absence of vital air give congelation to fluidity. What crime in physics, therefore, to admit of an elementary principle of fire?

From the earliest periods of time, the wisest men have allowed it. What crime also, to admit that the sun darts out light and heat to the limits of its appropriate system? The wisest men have also allowed of such emanations.

The fire which burns, is apparently nothing but a certain matter put in motion: but, all substances are not capable of causing the motion, of receiving, or even of nourishing it. This matter, however, evidently exists, and is what Stahl called phlogiston. Nature appears to afford an igneous, or inflammable fixed air, as well as a mephitic, or aerial fixed acid. Vital air, or as Scheele calls it, the air of fire, is demonstratively necessary on the surface of the globe, for inflammation. But, are the brilliant experiments of modern chymists relative to this vital air, (they will pardon my pyrrhonism) radically to extinguish the no less brilliant experiments of former chymists on phlogiston? An inflammable principle has been as ably supported as a principle of vital air. The inflammable principle exists in animal and in vegetable substances, in solids, in liquids, and in aeriform fluids. It passes from one to the other, as a common or universal principle; it is the cause of various combinations; it causes fermentations, effervescences, and putrefactions; it causes transudations, evaporations, exhalations, &c. Common terrestrial lights, I know, instantly die away, and disappear in a *vacuum*; a proof, no doubt, of the essential agency of vital air in terrestrial combustion. But the solar rays, in all the energy and strength of fire, dart through this very vacuum, and, in the *absence of all air*, give combustion. Is not the solar light then a matter different from the common terrestrial light? In this experiment of the vacuum, there is no need of the afflux of vital air, disengaged from the atmospheric air. The solar rays here appear to act integrally, and to have a decided effect independent of vital air; whereas, vital air is incapable of any decided inflammable effect without the solar influence, or without the aid of some phlogistic process.

The principle of fire, which is the cause of existence, is different from that of heat, which is the effect. Without the agency of the element of fire, there would be neither solidity, fluidity, elasticity, nor motion. Matter would be a shapeless mass, without energy or force. Light and heat are not distinct properties, they are merely effects. But, the element of fire is the first great link in the wonderful chain of nature. It is not only the cause of expansion and volatility, but it is likewise the cause of cohesion and of fixity. It is that which gives to minerals their solidity and brilliancy; to calcareous substances their consistency; and to organized beings their texture and vitality. The principle of fire indeed, the pure phlogiston, has been confounded with its modification, inflammable air. But the one is elementary, and invariable in its action; the other is a compound, and is various in its combinations. Heat has also been denominated a substance; but heat is only a quality, occasioned by an augmentation of volume, and a diminution of solidity. Its mobility, its inconstancy, the impossibility of fixing it, all prove this. Were heat a substance, and not the effect of a substance, how inconsiderable soever its density, it would in some measure augment the weight of bodies, and that in the ratio of its intensity. But the weight of a body is the same, whether heated or not heated. Neither heat nor light have any sensible weight. And yet, how slow is the developement of heat, to the astonishing rapidity of light! These two effects of fire, therefore, differ as intrinsically from each other, as they differ intrinsically from their parent element.

And here, I think, we may come to a conclusion. An emission and a circulation of solar particles are to me as satisfactory data to go upon, as an emission of odorous effluvia from a flower, or the circulation of the fluids of an animal, or of a vegetable. The rays of the sun, I consequently must hold to be material, and to be of the element of fire. Of what infinite importance do the presence of light and of heat appear to be to existence and to vegetation! In light and in heat we may see the principles of life, as in darkness and in cold we may see the principles of death. From fire, besides our own animation, we can trace the taste, the colour, and the perfume of the whole vegetable world. In pure phlogiston, we can trace the principles of existence, the soul of motion, the very nervous fluid, perhaps, which gives sensibility to man. In a word, from the orb of the sun I cannot but conceive light to be projected; and that heat is occasioned by collision or motion, and is fire only dilated by some specific cause: for there is a most striking analogy between bodies at rest in mechanics, and bodies that are cold in chymistry; rest being but a privation of motion, and cold being but a privation of heat. At the same time, I will not deny, that in the phænomena of terrestrial combustion, the presence and agency of vital air may be essentially necessary. Vital air, I know, is supposed to be the base of all acids, and has consequently been called by the French *la principe oxygene.* But vital air, to recur to an example, I have never found to abound more in the equatorial than in the temperate or frigid regions, or more in the summer than in the winter; and yet, why should there be in the neighbourhood of the line, or in the summer, if it be not occasioned by immediate solar influence, such unequalled heats, and such unequalled evaporation? Heat and light then, I mean such as come from the sun, I must believe to be independent of vital air, though terrestrial inflammation may not. I may be wrong; but, I have always looked upon the sun as the dispenser of positive heat, as well as of positive light; and I am not yet sufficiently convinced by any new, however celebrated theory, to relinquish what has ever, until lately, been the favourite, and, as it should seem, the self evident opinion of mankind.

Nor in truth, is there such a mighty difference between the old and the new theories. Lavoisier thinks that light, heat, and all the other remarkable phænomena of combustion, depend rather on a certain action of the air, than on the peculiar nature of combustible bodies; that the flame which then arises, is occasioned by the disengagement of the light which was combined with the pure air, not of that which existed in the combustible body. To pure air he ascribes that decomposition, which, according to Stahl and Macquer, takes place in the inflammable substance. Pure air, he considers as a compound of fire and another principle; and fixed fire, the disengagement of which is the principal act on such occasions, is, in his opinion, separated from the pure air, not from the combustible body. Now this fire or heat, which Lavoisier allows as a principle of pure air, and the disengagement of which he takes to be the cause of the sparkling flame and vivid heat which accompany the rapid combustion produced by that air, act nearly the same part with Stahl's phlogiston, or Macquer's fixed light; and consequently, as they all seem to be universally agreed concerning the existence of the principle, the only difference among them is, that one party believe it to exist in combustible bodies, and to be the cause of inflammability; while the other consider it as a principle of air, and ascribe inflammation to a different cause.

LETTER XV.

BESIDES the powerful agency of the solar rays, you will, from a former letter, have understood, that various philosophers have insisted not only upon the universal agency of fire on the surface of the earth, but have maintained, that there is the strongest reason to believe the existence of a central mass of internal fire. The doctrine taught by Burnet and others, together with the objections to it, you have had already before you. Both Des Cartes, however, and Newton, leaned in some degree to the same opinion. They both adopted the idea of a *considerable* internal heat. The latter, in his 31st question, thus expresses himself: "Si consideremus quam multum sit sulphuris intra terram, et quam calidæ sint partes interiores terræ; fontesque fervidos contemplamur, montesque ardentes, mephitesque subter terram subitaneas & vapores inflammabiles; coruscationes metallicas, terræ motus, exhalationes æstuosas & suffocantes, ventorum turbines, immanesque aquæ marinæ in cœlum usque elatos & contortos vortices; utique

intelligere poterimus, omnino ita comparatam esse terram, ut in visceribus ejus abundent vapores sulphurosi, qui cum mineralibus fermentescere debeant, & interdum ignem concipere, cum subitâ coruscatione & displosu; & si forte in cavernis subterraneis arctè inclusi contineantur, vehementer conquassare terram, & cavernas ejus disrumpere, quemadmodum cuniculi pulvere tormentario repleti terram suffossam mirâ cum violentiâ disjiciunt: quod cum accidit, tum vapores explosione ista generatos, per occultos terræ meatus expirare, æstuosque sentiri & suffocantes; procellasque, turbines & tempestates ciere, efficereque nonnunquam, ut terræ tractus de locis suis transportentur, ebulliatque mare, & guttatim subvehantur in cœlum aquæ, quæ deinceps acervatim & vorticoso pondere corruunt, quasi è nubibus effusæ."

That there are prodigious fires kindled in the bowels of the earth, may readily be believed. At the same time, sound reason would perhaps lead us to conclude, that the mass is not in continual ignition, but that it becomes accidentally generated. The materials unquestionably abound, but the cause is not always at hand which drives them into action. And experiment, it is said, strongly supports the conclusion; for it is

proved, that the heat of the earth, in certain situations, does not *increase* as we descend into it, but that at the greatest depths, it is nearly the same as the mean annual temperature. In the mine of Joachimstahad, for instance, in Bohemia, and reputed one of the deepest in the world, M. Monnet found the temperature at the depth of seventeen hundred feet to be 50°.

"The surface of the earth," says Kirwan, "is much heated during summer; but this heat descends very slowly, a great part of it being communicated to the air. During the winter, the earth gives out to the air the heat it had received during the summer. Thus, consequently, wet summers must be succeeded by cold winters. In all this we see," continues he, "nothing like the operation of a central heat." The fact, on the contrary, proves, that at a certain distance from the surface, namely, about 80 or 90 feet, the temperature of the earth varies little, and generally approaches to the mean annual heat. And thus the temperature of springs is nearly the same as the annual temperature, and varies very little in the different periods of the year. The greatest cold, if it lasts only a few days, even when below 0 of Farenheit, and when the earth even is not covered with snow, does not penetrate above twenty inches; and not above ten inches when snow lies on the surface." De Saussure likewise observes, "that *water* has never been found to be considerably warmer at the bottom than at the surface. The greatest difference that has ben observed," says he, "has been four degrees of Farenheit's thermometer. In latitude 55° S. according to Forster, the surface of the sea was 30 degrees, and at 600 feet, it was only 34 degrees of the same thermometer." The contrary indeed has been remarked, when the heat of the external air has exceeded that of the water. The bottom then has been found considerably *cooler* than the surface. Moreover, in addition to these facts, it may be presumed, that the heat of the sun does not penetrate the waters of the ocean to a greater depth than 150 feet; or the surface of the earth more than to 15 or 20 feet, for at that depth ice is preserved during the warmest summer.

After all, however, it is evident, there must be a heat, a principle of fire, independent of the sun, in the bowels of the globe; for otherwise men, animals, and vegetables, and in short, all nature would languish and fall into annihilation, during the six months absence of the solar rays from the polar world. Yet, we see there that existence goes on; that new generations arise, and that the fire of life circulates in the polar as well as in the torrid regions. Moreover, it is not altogether an established fact, that the warmth of the earth does not increase the deeper we descend into it. I am aware, that both what is agreed on one side and on the other, may have been the result of accidental, and not of permanently physical causes. No positive theory can be established, on a few solitary experiments. But, in the mines of Geromagny in Alsace, and at the depth of 600 feet, according to Mons. de Gensanne, the thermometer was found to be ten degrees above the freezing point, and out of the mines, where the solar influence could alone be felt, it was only two degrees above the freezing point. De Mairan moreover says, that, still prosecuting the descent, they found that the mercury, at the depth of 1350 feet, had risen to the 18th degree above the freezing point; the heat, as it were, increasing in proportion as they penetrated into the earth. But, in truth, if heat did not exist in the bowels of the earth, how should we have volcanos at the bottom of the ocean? How is it, that the sea at those profound depths, where the solar rays have no influence, does not congeal and form one body of ice? How is it that in the coldest region, the surface only is congealed, and that to an inconsiderable depth, in comparison to the mass of the waters? Whence come those tepid springs, which flow at Spitzbergen, in the 80th degree of latitude; and those magnificent jets d'eaux, which, from internal fires, receive their surprising impulse in Iceland? All these facts manifest the general dissemination of the principle of fire; and though they do not entirely go to the central fire of the philosophers, they yet establish a heat independent of solar influence, or of any planetary motion.

And this fire, we may be allowed to call concentrated or fixed, or phlogiston; for why should we not have fixed fire and fluid fire, as well as fixed air and fluid air, fixed water and fluid water? "Thus," remarks Franklin, "I have been always inclined to think that the fluid fire, as well as the fluid air, in the instance of plants, is attracted in their growth, and becomes consolidated with the other materials of which they are formed, and makes a great part of their substance; that when they come to be digested, and suffer in the vessels a kind of fermentation, part of the fire, as well as part of the air, recovers its fluid active state, and diffuses itself in the body, digesting and separating it; that the fire, so reproduced by digestion and separation, continually leaving the body, its place is supplied by fresh quantities arising from the continual separation; that whatever *quickens* the motion of the blood in an animal, quickens the separation, and reproduces more of the fire, as exercise; that all the fire emitted by wood and other combustibles when burning, existed in them before in a *solid state*, being only discovered when separating; that some fossils, as sulphur, sea-coals, &c. contain a great deal of solid fire, and that, in short, what escapes and is dissipated in the burning of bodies, besides water and earth, is generally the air and fire that before made parts of the solid; and this theory has been taught by all chymists. "Indeed," as Dr. Black observes, "if we can believe our senses, we must suppose that heat and light proceed from the evolution of phlogiston."

Again, look at the properties and operations of electricity. Electric fire acts upon bodies, in the same manner that common fire does; it sets fire to combustible bodies, dissolves iron, and calcines it; it increases the bulk of alkaline air, and makes it inflammable. All these effects are peculiar to fire; but they are much stronger than those of any fire which art can produce.

Electric fire, in passing through a bar of iron, will melt it, though its passage is so wonderfully quick, as to be performed in an instant of time too short to be measured. Now, we are certain, its power to melt the iron at once, must be from its fire; and no fire that we can produce, will have the same effect upon the iron, till after a very tedious operation. Heat only melts metals; the electric fire dissolves them by only one discharge of the battery. What is this? Is it fire—caloric—phlogiston—or what Priestley sometimes calls the principle of alkalinity, and sometimes the principle of acidity? It is immaterial to say which. Alkaline salts, oils, acids, and other phlogistic bodies, when decompounded, give out considerable quantities of fixed fire. Acids, as I have already remarked, are the substances best fitted to concentrate it; in like manner, as the vegetable acid, or fixed air, water and earth, are employed in wood, bitumens, &c. and the mineral acids, in sulphur, nitre, &c. All bodies, which contain a great proportion of fixed fire, are formed of acids, water, and earth: and hence, the reason why both phlogisticated and dephlogisticated airs contain an acid.*

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* Dr. Harrington.

From the whole then that we have thus collected of the researches of men into the principles of the element of fire, we may fairly look upon natural bodies,* as floating in an ocean of what the poet properly terms *ακαματον ϖυρ*, *indefatigable fire*; and that the bodies sustained in it, are hard and soft, fluid or solid, lax or firm, rare or dense, expanded or contracted, according to those changes in the temperature of this element which keep up a constant *systole* and *diastole* through the whole frame of nature. And hence we may see the reason why Lactantius, among other arguments to shew the superiority of man in the creation, and the immortality of his nature, says, "That of all the creatures known to us, *man* is the only one, who has the use and command of the element of fire. With that heavenly substance he is made familiar, without which there is neither *light* nor *life*; while the most powerful and ferocious beasts are alarmed by it, and fly from it. To man," says he, "is thus entrusted a power, the most similar to the power of God himself, who has the direction of all the elements. How dreadful had it been, had the brute creation been gifted with the same glorious privilege! If there had been the use of fire, where there is not the use of reason! When the ancient philosophers contemplated this wonderful privilege of man, his enjoying the use and the dominion of the element of fire, that Παντεχνου πυρος σελας, the *brightness of fire, the universal artificer!* as Eschylus expresses it, the likeness of God himself! they persuaded themselves, as it was a privilege too great for him in the beginning, that it must have been originally *stolen* from heaven; and that this very theft was the crime which brought all manner of evil upon the world!

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* Jones's Philosophy of the Elements.

LETTER XVI.

NEXT, if not equal in rank to fire, comes the element of *air*; an element of which avarice cannot deprive us, and which power cannot monopolize.* The treasures of the earth, the verdure of the fields, and even the refreshment of the stream, are too often seen almost entirely appropriated to the luxuries of the great; while the less fortunate part of mankind stand humble spectators of their encroachments. But the air, no limitation can bound, nor any landmarks restrain. In this benign element, all mankind have to boast of an equal possession; and for this we have all equal obligations to heaven. While we live, we consume a part of this element for our sustenance; and when we die, our perishing bodies render back the supply, which, during life, we had accumulated from the general mass.

Air, in philosophy, is a light, fluid, transparent substance, surrounding the earth to a very considerable height. The word in Greek is *αηρ*. The ancients understood the nature of this element.* They looked upon it as a general *menstruum* containing the volatile parts of all the bodies and substances in nature; which being combined and differently agitated, produced that variety of fermentations, meteors, tempests, and other effects, which daily fall under our observation. They knew also its *weight*, although they have not transmitted us any experiments on that head. The air is generally esteemed a *fluid*, though it differs from the general nature of fluids, in these particulars: 1. In being compressible, a property unknown to any other fluid. 2. In being uncongealable, or incapable of being fixed by any known method, as all other fluids may. 3. In being of a different density in every part, decreasing from the earth's surface upwards; whereas other fluids are of an uniform density throughout. The air is therefore a fluid *sui generis*, if it be properly any fluid at all. In the heathen mythology, it was worshipped by some sectaries, under the names of *Jupiter* and *Juno*; the former representing the superior and finer part of the atmosphere, and the latter the inferior and grosser part. Of the *internal* structure, however, of this element, it is more than probable we shall never attain the knowledge.

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* Animated Nature.

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* Recherches sur l'Origine des Découvertes attribuées aux Modernes.

It is too subtile, too tenuous a substance to be perceptible to us with all the advantages of the finest glasses. But its properties are well ascertained; and the most essential are fluidity, gravity, and elasticity.

From the researches made into the nature of this imperceptible, but most powerful agent, it has appeared, not only that it is a constituent ingredient in animal and vegetable life, but that it is essentially requisite in every stage of both one and the other. Nay more, besides animal and vegetable life, it has been found, that it is no less indispensably necessary to the existence of sound, of fire, and of explosion. For example, as in an exhausted receiver an animal cannot live, so neither can a bell be heard, an inflammable body be kept burning, nor gun-powder be exploded, though made to fall on iron which shall be red hot. And in proof, with regard to the first of these instances; if the air be extracted that is in the body of an animal, the animal is squeezed flat by the pressure of the external air, and expires in an instant. On the other hand, if the circumambient air be exhausted, the internal air dilates itself to such a degree, that the animal will swell till it bursts. The weight of the air is equal to thirty-two feet of water, each cubic foot weighing about seventy pounds; so that a column of air, a foot in diameter, weighs about 22,000 pounds weight. Yet, as it acts with equal force on either side, neither animal nor plant is injured by it. Thus, place a flat surfaced bottle empty on its side, and the elasticity of the air within it will prevent the weight of the atmosphere from breaking it: exhaust, however, the air, and the force of the external air on its surface will make it fly into a thousand pieces.

This elasticity of air arises from the particles not joining so intimately as the particles of other fluids. A particle of fire being repulsive, forms a center to every certain number of particles of air, and so keeps them in a state of separation. And hence too the reason why air can be so greatly compressed. In regard to weight, the power of gravity in air is very considerable, though not equal to its elasticity, or to its repulsive force. Were the power of gravity to be for a moment suspended from matter, and the power of elasticity to remain, the atmosphere would instantly be dissipated through the regions of space. * The particles of air at the highest elevation,

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* Martin's Philosophy.

elevation, are the least affected by the power of gravity, are the least heavy, and are those which are kept at the greatest distance from each other. Close to the surface of the earth, the reverse is the case, and thence density and rarity. The weight and the elastic force being always equal, an universal equilibrium is always preserved in the atmosphere.

The agency of the air is wonderful.* It is in the first instance the vehicle of all kinds of odours, by the transportation of which we are acquainted with the good or with the bad qualities of food, and of innumerable other things. It is equally faithful and diligent in conveying to us knowledge, through the ministration of sounds, at the rate of 1142 feet per second, which may be looked upon as so many couriers, who run backwards and forwards to bring us news of transactions which occur at a considerable distance. It is likewise the channel of light, which is not one of its least phænomena; a substance possessing a surface sufficient to reflect the light, and yet not dense enough to be obvious to sight. And happy for us it is so; for had we but a glimpse of the air, we should never have any distinct view of any other object. It would indeed be a misfortune to us of the most serious kind. The exhalations of the earth would then be discovered; the least smoke would disfigure the rich landscape of the universe; we should discern all those gross humours, which an incessant perspiration drives from the bodies of all animals; and all the filth that arises from vile receptacles. Life, in short, would be disagreeable and irksome: we should be miserable,and should fly from the annoyances which would be the unavoidable result of such a faculty.

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* Spect. de la Nat.

But if our obligations to the great Author of all, for the advantages we particularly derive from the element of air, are thus great, what should not our gratitude to him be, when we further contemplate its vivifying energy through the other parts of the creation? The universe abounds with an infinite variety of living creatures. Some are inhabitants of the air, others range round the fields, or crawl upon the ground. Thousands reside in the utmost recesses of the thickest woods, in the hearts of leaves, and under the bark of trees; some in the chinks and crevices of walls, and others in the most gloomy caverns. The very bowels of the earth are hollowed, and filled with inhabitants. All these animals, how different soever from each other, with respect to their nature and way of life, enjoy the same benefits in common. They all of them partake and breathe the same fluid, air.

The subject of air, which we are thus about to consider, like that of every other branch of true philosophy, though known to the ancients, and in some degree investigated by our forefathers, by Friar Bacon in particular, may yet very fairly be supposed to date its origin from the beginning of the last century. Drebbel, by the invention of the thermometer, and Toricelli, by that of the barometer, undoubtedly gave it birth.* As a science, it must be confessed to be of the greatest importance. Our very mental powers are affected by it. We are gay or sad, according as the heavens are cloudy and serene. Is the air thick and disturbed, we feel a sadness at the heart, which vanishes as soon as it is restored to its wonted serenity. And hence it has with justice been remarked, that the improvements that atmospheric air, and the other permanently elastic fluids, have received, have been of more advantage to mankind, and have reflected more honour upon the philosophers who have made them, than those of any other branch of natural philosophy whatsoever.

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* Kirwan.

LETTER XVII.

AS the part most familiar to us, let us first turn our consideration to that most stupendous body of air, the atmosphere. The atmosphere which every where surrounds our globe, consists of a pellucid, elastic, and apparently homogeneous fluid, which we denote by the name of common, or atmospheric air.* When more closely examined, it is found to contain, besides vapours, which vary wonderfully, according to the diversity of situations and winds, *three* fluids mixed together, and widely differing in their nature. The largest part, which certainly exceeds the others three times or more in bulk, is neither fit for supporting fire, nor for respiration; it probably derives its origin from the vital part, in consequence of some changes not yet perfectly known, perhaps proceeding from the addition or subtraction of phlogiston, and may therefore be called *corrupted air*. The next is that which is called *dephlogisticated*, but which Bergman, with the historian of the French Academy, thinks should be distinguished by the appellation of *vital*,

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* Bergman.

vital, and which differs widely from the preceding, being not only fit, but indispensably necessary to fire and respiration, every other air being *mephitic*. The third is the *aerial acid* or fixed air, which forms the smallest part of the atmosphere, scarcely even amounting to one sixteenth. Nor does the *vital*, indeed, ever amount to full one-fourth of the atmosphere.

Doctor Priestley, to whom the science of air is much indebted, says, " The air of the atmosphere is a fluid, consisting of an earth and a spirit of nitre, which has weight, but is elastic; that is, that it is compressible and dilatable: that it is a compound, a dephlogisticated air, in a state of deprivation: that acid air, and phlogiston, seem to be the only essential principles of common air: that it is probable also, when we consider the prodigious quantities of inflammable air, produced by the burning of small pieces of wood and pit-coal, that the volcanos, with which there are evident proofs that almost the whole surface of the earth has been overspread, may have been the origin of our atmosphere, as well as (according to the opinion of some) of all solid land: and that the seas, which it is probable to suppose, originally covered the earth, imbibed the superfluous phlogiston,

ton, or the acid vapour, exhaled from the seas, might have united with it, and hence the atmosphere. "But however this may be," says Priestley, "the air, though it has been denominated *a simple elementary substance*, indestructible and unalterable, at least as much so as water is supposed to be, is yet far from being an unalterable thing; for the phlogiston, with which it becomes loaded from bodies burning, and animals breathing in it, so far alters and depraves it, as often to render it altogether unfit for the purposes to which it is subservient."

The atmosphere, in short, in the words of a learned prelate,* may be looked upon not only as the general receptacle of the aqueous vapours of the sea and rivers, but likewise of all mineral exhalations; of the streams which are constantly arising from the perspiration of whatever enjoys animal or vegetable life, and from the instantaneous putrescency of those substances when deprived of life; of the smaller seeds of terrestrial and aquatic plants; of the eggs of an infinity of species of imperceptible animalcules; of the acids and oils separated by combustion from all sorts of fuel; of the matter of light; of electric effluvias; and of a variety of other substances, which are elevated, and for a time kept suspended by natural and accidental causes. And from these sources are derived those various impurities, which have been discovered in all atmospherical water.

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* Bishop Watson.

Such then we may suppose to be the constituent parts of the atmosphere. But, a question naturally occurs—Is the whole of the immense fluid, which thus surrounds us, of the same materials, or do the strata differ? And supposing them to have distinct properties—To what height may we conceive the atmosphere to extend? Here, indeed, are points which have much engaged the attention of philosophers. "The first stratum," (for we must admit of strata, says the celebrated French naturalist*) of the atmosphere is filled with vapours exhaled from the surface of the globe, both by its own heat, and by that of the sun. This extends to the height of the clouds, where they are condensed and suspended in the form of clouds. Beyond this middle region, the vapours rise, but cease to be visible, except when a part of the cold stratum seems to be pushed back towards the surface of the earth, and when the heat escaping from the earth, being for some time extinguished by the rains, the vapours then collect and thicken around us, in the form of mist and frost. The clouds are fixed in an equipoise, which they cannot surmount. In summer they are higher than in winter, and still higher in warmer climates. In regard to the height of the atmosphere, it was long thought to be not above 15 or 20 leagues. In 1676, it was in different countries computed by different observations of a large meteor, that the elevation of the meteor was at least fifteen leagues. But this elevation is not to be supposed the ultimate stratum of the atmosphere. A famous *aurora borealis* was observed in 1726, and calculated to be considerably higher than this meteor from the surface of the earth; and the aurora borealis, we know, is generated in the atmosphere. But the real height of the atmosphere is a problem that never can be resolved. To infinity it may extend itself, at least it may expand till the atmosphere of every body in each system, and of all the systems in the universe meet with each other, and mixing, constitute that fine *ætherial medium*, which fills the abyss of space.

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* Buffon.

Two circumstances incline me to believe," says Jones,[*] "that after the many useful and curious discoveries which have been made, the atmosphere is yet but imperfectly understood. The one is, the violent force of the wind on the top of Ætna, *above* the regions of the clouds, when the air, by the barometer, seems to have lost one-third part of its density. The other is, the sounding of explosive meteors from the height of sixty or seventy miles and upwards in the air. In this region, where, by calculation, the air is much *rarer* than the best vacuum in an air-pump, combustible matter is collected in great abundance, which must be derived from the earth, as the pure matter of the heavens cannot be supposed to furnish it out of itself. In this region, inflammable matter *explodes* and *burns* with a vivid light, though the matter of lightning is dissipated in a vacuum, and what is more surprising, sound is thence transmitted to the earth; which, as experiment shews, cannot be communicated without the intervention of the air as its vehicle, or the vibrations of some continuous solid body. Doctor Halley gives an account of a meteor seen all over England, which, by a calculation sufficiently accurate, was seventy miles high, as bright as the sun; and the explosion of it, which was as loud as a broadside of cannon, was heard all over Devonshire, Cornwall, and the neighbouring coun-

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[*] Philosophy of the Elements.

ties,

ties, and shook the houses, as if great guns had been fired near at hand.

Here then we have it ascertained almost to demonstration, that at the great height of seventy miles, the atmosphere possesses properties in every respect correspondent with those of the stratum floating immediately over the surface of the earth. But yet the indisputable and progressive rarity of air in the ratio of elevation, renders this matter very difficult of comprehension. The density and weight of air are every where variable, being greatest at the surface of the earth, and decreasing gradually upwards; therefore, though the air near the earth be heavier than vapour (though vapour be visible), yet as its gravity decreases, it will at length become lighter in its upper parts; and, in one particular region between, it will be equally heavy with the vapours themselves; whence it must follow, that the vapours will rise from the surface of the earth to this part of the atmosphere; and since all the air above is lighter, they cannot possibly rise higher. Buffon, indeed, makes an attempt to unravel this mystery, and at the same time to account for explosions in general in the elevated regions of the atmosphere. "As cold," says he, "condenses as much as heat rarefies the air, and, as in proportion to the elevation, the cold increases, does it not follow, that the degrees of condensation of the air correspond to the degrees of cold? Hence this condensation of the air by cold, in high regions of the atmosphere, should compensate the diminution of density produced by a decrease of the incumbent weight; and of course the air should be equally dense on the cold summits of mountains as in the plains. The air," continues he, "though compressible, appears to be equally dense at all heights; and I cannot help believing, that the atmosphere extends not so high as has been supposed. The total thickness of it, for instance, may not exceed three leagues, instead of from fifteen to twenty, as has been conjectured. The winds on mountains are found as strong as those on plains; whereas, on the old hypothesis, they should be otherwise. Birds and men respire as freely at a great height as on the surface; but if the air were one-third less dense, this respiration should not only be injured but stopped, as happens to animals in air-pumps, when one-fourth, or one-third of the air contained in the receiver is exhausted."

However this may be, and you will recollect what De Saussure has said on the subject, the

fluidity

fluidity of this heavy elastic body, the atmosphere, is such, that no cold can *destroy* it. Its natural state seems to be that of rest, which it always endeavours to keep, or recover, by an universal equilibrium of its parts. When, therefore, this natural equilibrium happens by any means to be disturbed, then necessarily follows a motion of all the circumjacent air towards that part, to restore it; and this motion of the air is what we call *wind*. The most general causes of wind are, *heat*, which by rarefying the air, makes it lighter in some places than it is in others; and *cold*, which by condensing it, makes it heavier. The true cause of the winds, however, is not yet thoroughly ascertained. As distinguished at present, they are divided into three grand classes. 1. The common, inconstant, or variable winds. 2. The whirlwinds, tempests, and hurricanes. And 3. The constant or stated wind usually called the trade wind; and in some parts of the world, the monsoon.

“The winds,” says Buffon, “may be divided into zones. The east wind, which extends 25 or 30 degrees on each side the equator, exerts its force round the globe within the torrid zone. The polar wind blows with equal constancy in both the frigid zones. The winds peculiar to the temperate zones may be considered only as currents of air, produced by the combination of the two principal winds, which give rise to all those that come from the eastern points; and the west winds, which are common in the temperate zones both in the Atlantic and Pacific Oceans, may be considered as reflections from the continents of Asia and America, but deriving their origin principally from the east and the north winds."

The reasons assigned for the equatorial winds are these: as the earth revolves on its axis from west to east, the middle part of the earth, and consequently its atmosphere, becomes very much heated by the sun; by which means it becomes more rarefied than other parts remote from the equator or torrid zone; on this account it becomes also lighter. The air, therefore, from the polar parts on either side being heavier, continually sets in towards the equator, to restore the equilibrium of the atmosphere, which constantly alters by the refraction of the sun. Thus there would be a motion produced in the atmosphere from north to south towards the middle parts of the earth, which would make to us a constant north wind, and to the people on the other side of the equator a constant south wind, if there were nothing else intervening. But the parts of the earth under the sun, being the most considerably heated and rarefied, and as the earth turns eastward, the point of greatest rarefaction in the air is constantly shifting towards the west; the western and eastern air, on both sides, flows towards this point; but as that on the west meets it, and that on the east follows it, the motion of the western air is lessened, and that of the eastern air increased; and therefore that of the eastern air prevails against the motion of the western air; and so there would be a constant east wind produced in parts under, and near the equator, if the body of the atmosphere were to be affected in no other direction; but since the several parts thereof are urged in *two directions*, a motion results thence between both, and consequently a *north-east* wind is produced on the north side of the equator; and a *south-east* wind in the southern hemisphere. And these extend nearly 30 degrees on each side of the equator.*

The direction of the *monsoons* is not altogether, though it is in some respects, the same as that of the general trade winds. The cause of the monsoon is this: The sun, during its passage through the northern signs, *rarefies* the northern parts of the atmosphere most, which is still further increased by the great reflection of the solar rays from the sandy desarts of Arabia and the Indian coasts. All this time the currents of air come into those seas almost in a south-west direction. But when the sun enters the southern signs, it carries the point of greater rarefication on the other side of the equator, occasioning a contrary current of air. In accounting for the monsoons, however, it is necessary to mark the peculiar circumstances which obtain in the *Indian Ocean*, and which are not found in the Atlantic or Pacific Oceans. They seem to be these: That the Indian Ocean is bounded to the northward by shores whose latitude does not *exceed* the limits of the general trade winds, and that the general trade winds fall on what mariners call *lee shores* to the westward. The sun being twice in the year vertical in the equator, and never departing thence more than 23½ degrees, causes the air in that climate to be hotter than at any other place on the ocean. Such a rarefied space must extend across the Indian ocean, and produce a S. E. wind to the southward, and a N. E. wind to the northward of the equator, over which, in the upper regions of the air, the winds return in the contrary direction. This we accordingly see happen in the months of October, November, December, January, February, and March. But, when the sun declines to the northward, and heats the lands there, the air contiguous to those lands becomes rarefied, and the lower air has a tendency to move that way. This tendency increases, as the sun advances further north; so that the whole body of the lower air to the northward of the equator moves towards the northern lands, notwithstanding the equatorial rarefaction. If the rarefaction on the surface of the northern land be greater than that at the equator, the wind blows to the north, and the contrary happens when the equatorial rarefaction is greatest. Thus then it is, that the existence of land, and the situation of that land for reflecting the rays of the sun, causes the monsoons. Were there other lands, on other parts of the globe, and those as well situated for the reflection of the solar heat, monsoons would not be peculiar to the east. In their commencement, to use a seaman's expression, they are always found at first to creep along shore; they then spread into the ocean. At first they are feeble, they afterwards become vigorous; they then gradually diminish, and finally come to a change, and this twice in the year, agreeably to our solar progress.

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* Martin's Philosophy.

These, or some such like, are probably the causes of the winds that prevail in the Indian ocean.* But the observations we are in possession of, are too few and too inaccurate for the purpose of forming a theory. On the same principles it will not be difficult to account for the *land* and *sea breezes*, in warm regions. For, because the land is heated in the day time, the wind must blow in shore to supply the place of the ascending rarefied air: and in the night, the land cools and condenses the air, occasioning the land breeze. For instance,† the surface of the earth is more suddenly heated by the rays of the sun than that of the sea, from its greater density and state of rest; consequently, it reflects those rays sooner, and with more power; but, owing also to its density, the heat is more superficial than that imbibed by the sea, which gets more intimately warmed by its transparency, and by its motion continually presents a fresh surface to the sun. Consequently the land breezes are of greater continuance than the sea. Islands, from the reflected rays of the sun, often appear as with a glory round their heads. And hence in short it is,‡ that air incumbent on seas, or large tracts of water, is generally many degrees

warmer

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* Nicholson's Philosophy. † Marsden's Sumatra.

‡ Kirwan.

warmer in winter, and cooler in summer, than air incumbent on land; because land is more susceptible of both heat and cold than water, and in general participates of the temperature of the subtance with which it is in contact. Land takes eight or ten degrees more heat than the sea in summer; and is eight or ten degrees colder in winter in the same latitude. And hence the cause of those low mists which are so often seen hovering above the surface of rivers and other waters in the evenings, towards the end of summer: for as the waters retain their heat longer than the earth after the sun withdraws, the moisture which was raised during the heat of the day to a small distance from the earth's surface, is quickly condensed by the cold of the evening, and falls down in copious dews; whereas that which is above the surface of the waters is more slowly condensed, by reason of the heat, which that element retains longer, and hovers at a small distance above it in the form of a dense vapour, which slowly subsides as it loses its heat. Even in our own climate, the land and sea breezes are often sensibly felt during the summer season; although from the length of the day, and shortness of the night, the difference between the heat of these is far less than in warmer climates.

From what we have thus seen of the equatorial and other regular winds, the transition to the opposite kinds may be thought of no very great difficulty. And the fact is, there is scarcely any thing more readily to be accounted for. I shall not at present, however, trouble you with the enumeration of each of the particular causes. But, as far as the sun is concerned, the variety of winds, to which the northern and southern parts of the world are subjected, may be conceived to be occasioned by the comparatively small degree of influence the sun has in those parts, and the consequent situation of the air, which being *undetermined* as to any particular point, is continually shifting from place to place, to fill up the equilibrium, which may have been destroyed by the influence of the sun in other quarters, the rising of vapours and exhalations, the melting of snows upon the tops of mountains, and other circumstances. The variations in wind, indeed, are at all times occasioned by the elasticity of the air, which, in whatever manner compressed, is forced to a re-action. But, besides the fluctuations occasioned by condensations, and by dilatations, by fermentations on the surface of the earth, and by fermentations in the clouds, there are still also powerful collateral operations always going forward in the bowels of the earth. This may appear strange. But, is not the approach of a storm often seen to be predicted by the actions of animals? They feel at the surface, that the electric fluid, or some other vapour, is rapidly rushing to more elevated regions, thereby disturbing the equilibrium, and leaving the other constituent parts of the atmosphere in perturbated dissonance and confusion. Is not this electric or other discharge also observed to be in certain countries nearly periodical? In the east and in the west, after a certain lapse of time, a sufficiency of matter is seen to have accumulated. Tempests consequently burst forth. The period of tranquility again is to be guessed at, if not calculated. But, how often do we see the sea to be agitated, without any external appearance of change in the atmosphere? Musschenbroek, therefore, was probably not far from the truth, when he supposed, that one year with another, and in the same place, in insular situations and sea coasts in particular, the same quantity, and the same direction of wind, though irregularly, are annually produced.

This dominion of the winds would seem to be confined to the sea, but it is not so.* Winds are capricious and violent. They rush with irresistible fury. They excite impetuous commotions. They not only raise mountains of sand in Arabia and Africa, and overwhelm large plains, but they carry sands into the sea, and form banks, and even islands. It has even been observed, that no cloudy and moonless night, which is very windy, is dark; as if the wind by its motion always raised a light in some degree, through the agitation of the elements, and the collision of the particles that are floating in the air. Hurricanes are the scourge of the Antilles, of Madagascar, and other countries. They sweep away trees, plants, cattle, and the soil that nourished them. They drive back, they annihilate rivers, and produce new ones. They overthrow rocks and mountains. They scoop out holes and gulfs in the earth, and totally change the face of those unhappy countries which give them birth. The heat of the sun, as we have observed, is the most powerful cause of these winds; but the force of the sun's attraction upon the atmosphere, and even that which is supposed of the moon (which, however, I am much inclined to deny, for has the moon ever been observed to have an influence on the trade winds?) are inconsiderable, when compared with the effects of hurricanes. For though the air is elastic and 800 times lighter than water, the motion produced by attraction cannot exceed what is excited in the waters of the ocean by the same causes; for the action of gravity being proportioned to the quantity of matter, it must elevate a sea of water, of air, or of quicksilver, nearly to the same height. This has been proved by D'Alembert. This part of our subject, however, will more particularly engage our attention at a future moment.

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* Buffon.

The atmosphere, as we have already traced it, cannot be the same at all heights, although the phænomena which we have taken notice of, are most difficult to be accounted for. Different kinds of aeriform fluids, immiscible with each other, or only susceptible of mixing to a certain degree, must enter into its composition, and occupy the place in which their specific gravity will naturally fix them. Thus, by the *barometer* we readily ascertain, that the higher we ascend from the surface of the earth, the lighter becomes the air, for the quicksilver descends in proportion, the tenth part of an inch for every ninety feet. Not that in every respect, the barometer is implicitly to be relied upon, for a superior stratum of the atmosphere will fall sometimes, when a cold wind in the upper regions passes over a country, the lower strata of whose atmosphere are specifically lighter, and hence a low state of the barometer (even on the surface) will precede such extraordinary cold.* And it is from this reason probably also, that Holland often experiences a degree of cold greater than countries placed under higher latitudes; for Holland being a very moist country, its atmosphere abounds more in vapours, which render it specifically lighter. Thus, during the great cold of January 1783, the barometer was lower than it was known to be for fifty years before during that month; and Muschenbroek remarked, that in winter, when the mercury in the barometer descended, the cold increased.

But, it is not material to our present purpose, whether the descent of the quicksilver be occasioned by the decreasing density of the atmosphere, or by the cold which results from a diaphanous medium. The point seems to be irrefragably established, that the atmosphere cannot, with more propriety, be considered of the same consistency in all its parts, than the vulgarly received opinion, which supposes it heavier on a cloudy, lowering day, than on a fine, serene, transparent one. As the density of the air, therefore,

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* Kirwan.

fore, is greatest at the surface of the earth, it is natural to conclude, that there the wind must be most violent; and this conclusion,* I apprehend, is just, when the sky is serene; but, when it is charged with clouds, the action of the wind will be most violent at the height of the clouds, which are denser than the air, as they fall in the form of hail or rain. In general, indeed, the winds are more violent, in proportion to the elevation of the ground, till they arrive at the ordinary station of the clouds; and beyond this the sky is generally serene, especially in summer, and the wind gradually diminishes: it is even said to be altogether imperceptible on the tops of the highest mountains. But, of the common power of winds, that which is *reflected* is the most violent, and that in proportion to the vicinity of the object by which it is reflected; and the reason is evident. The air in a direct wind acts only by its own *celerity* and its *common volume*; but this volume, or mass, is considerably augmented by the compression it receives from the obstacles by which it is reflected; and as the quantity of every motion consists of the celerity multiplied by the volume, this quantity is much greater after being compressed than before. It is a volume of common air which acts in the first case, and a volume of air of double or treble density which acts in the second.

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* Buffon.

The greatest violence, however, of the winds in the strata of the atmosphere, nearest the surface of the earth, is during spring and autumn, * and not in winter and summer. For this fact several reasons may be assigned. 1. In spring and autumn the tides are highest, and consequently the winds they excite are most violent. 2. The motion produced in the atmosphere, by the action of the sun and moon, must likewise be greatest about the equinoxes. 3d. The melting of the snows in spring, and the condensation of the vapours which are exhaled in summer by the sun, and which fall down in autumn in the form of rain, produce, or at least *augment* the force of the winds. 4. The transition from heat to cold, or from cold to heat, must create considerable augmentation and diminution in the volume of the air, which alone is sufficient to raise great winds. And these reasons receive additional support from a fact closely analogous, namely, that the coldest weather, in all northern climates, generally prevails about the middle of January, and the warmest in July; though, astronomically speaking, the greatest cold should be felt at the latter end of December, and the greatest heat in the latter end of June ; but, the earth requires some time to take, or to lose the influence of the sun, in the same manner as the sea with respect to the tides.

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* Buffon.

Besides those which we have already mentioned, there are a variety of other causes, which, when variously combined, are adequate to considerable effects in the atmosphere. Of all winds, however, none ever puzzled ancient philosophers more than the east wind which predominates in Europe. The cause they conceived to be the diurnal motion of the earth, not recollecting that no fluid, which surrounds the earth, can be affected by its rotation ; that the air must move along with the earth itself; and that the rotatory motion is equally imperceptible in the atmosphere as on the surface of the earth. The true cause is, that Siberia being the most elevated land of the old continent* (Mexico of the new, being 5491 feet above the level of the Pacific, and Quito, 9240) that is, being from 2500 to 3000 feet above the level of the ocean, the north-east winds proceeding from this country to Russia, Poland, Germany, England, and France, must be colder in proportion to the latitude, than those that blow on Sweden or Scotland; and colder than the more northerly winds that come to us over a large tract of sea. Now, Siberia is at least 2800 miles to the east of London: yet, notwithstanding, it is thence the wind is derived to us; for, according to the computation of one of the most accurate philosophers of the present age, (Mr. Smeaton) a common high wind travels at the rate of thirty-five miles an hour; so that three days only are required for its journey from Siberia. A balloon, indeed, has been estimated to have gone 120 miles in two hours; and an extraordinary gust of wind in England, in 1703, was calculated to have had a velocity of fifty miles in the hour.* Its general current, however, in a storm, may be estimated from sixty to seventy miles an hour.

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* Kirwan.

Thus we see that the winds are in various ways, not only salubrious but most beneficial to man. Their continual vicissitudes give a turn to the dispositions and productions of nature; they correct those ill consequences which would unavoidably flow from a too tedious inactivity and state of rest; and, in short, invigorate and purify the air, by keeping it in perpetual motion. Without them, our habitations would become unwholesome, and Geneva, or London, would in a short time be as nauseous as a common sewer: in a word, all nature would languish and die away. Moreover, as the atmospheric air may be considered, in its purest state, as a commixture of an acid and water, and a fixed fire, or phlogiston, so may it be stiled the principal agent in combustion. For a combustible body, as I have already noticed, though fire be applied to it, will not burn without the agency of an aerial substance. Atmospherical air being a compound of a mild acid, and of a mild, not a high concentration of fixed fire, parts with its own fixed fire, when actual fire is applied to it; however, the heat it produces is not powerful enough to keep the air burning, or decompounding its own fixed fire, unless it be exposed to some combustible body, having a high concentration of fire. Again, if fire be applied to a combustible body, not having the aid of this compound, it will not burn; for its fixed fire being so closely and strongly attracted, it renders it impossible to be decompounded. This is strikingly confirmed in dephlogisticated nitrous air. If this air be found not strongly saturated with phlogiston, it will allow a candle to burn in it with a bright and vivid flame; but, if it be highly saturated, it will burn with greater vehemence, and the flame will extend over the greater part of the air; that is, the flame will become extended from the candle, and more of the air will be burning at the same time; and if saturated with a still greater quantity of phlogiston, it will all take fire together, and burn with an explosion like to that of inflammable and atmospherical air; the agent and the principle being both in the same body.

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* Derham.

Air is a combustible body, as well as the body which it consumes. Atmospherical air being only a weak saturation of fixed fire, forms only a weak combustion; therefore, bodies burning in it, burn gently, consuming themselves in a slow and gradual manner. But, artificial dephlogisticated air, having *a higher saturation of fixed fire*, or phlogiston, allows a substance to burn with a more extended flame, and with partial explosions.* And, if a still higher saturation, being in the first instance an agent to produce ignition in another body, it will in this case become both agent and principle, and will decompound itself. For Dr. Priestley found this air with so high a saturation, as to burn and explode like inflammable air; and upon a particle of fire being added to it, it immediately consumed itself. The nitrous acid, or the dephlogisticated marine acid, when mixed with essential oils, or the volatile alkali, will promote ignition. The electrical spark, or fire, applied to atmospherical air, will gradually, and by a slow process, decompound it. Ignition depends upon *fixed fire being set loose*. Thus, let different metals be exposed to the dephlogisticated marine acid air, such as iron, copper, lead, &c. and ignition will immediately take place; and this owing to the marine acid air decompounding the phlogiston, and setting the fire loose. In the calces of these metals, there is no *oxygene gas* to be found. Attrition also acting mechanically, by dissolving the union of phlogiston, and setting the fire loose, generates ignition. In a word, no bodies but those which are phlogistic, will produce fire: at the same time, it will be allowed that Bacon, and others, were right in believing heat to consist in motion; this exception alone always attended to, that such heat is to be attributed solely to those peculiar particles of fire or phlogiston, for *the motion of other bodies will not produce it.*[*]

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* Dr. Harrington.

In opposition, indeed, to what I have above said touching the salubrity of winds, many instances may be adduced of the pestiferous and fatal changes which the atmosphere partially undergoes, especially in Africa and Asia. To enumerate them would be tiresome. The sirroco, and other winds, sometimes prevalent in the southern parts of Europe, are well known. The following, however, as its influence is so singularly extensive, may not, as an example, be unworthy of notice. The *Samyal* wind, which prevails for certain days in the year, not only in Egypt, but in Arabia, Syria, Persia, and India, and even in Africa and Spain, is so disastrous in its effects, that every thing in nature seems to yield to its power. Man and animals immediately fall victims, if they be surprised by it in its fury. It seems as if it had the faculty of instantaneously pumping out life, and of evaporating the first principles of existence. This wind, however, and those similar to it, it is curious to know, always proceed from desart countries. It is the action of the sun on sand, not tempered by the intervention of forests, rivers, or lakes, which renders their heat and aridity so destructive. In Bruces's and in Volney's Travels, you will see much on this extraordinary subject; and to those entertaining writers I refer you, requesting you only to bear this in remembrance, that stones or sand contain less specific fire than earth, this being always moister; hence they heat and cool more readily, and to a greater degree, which accounts for the dreadful heats of the desarts of Arabia and Africa, and the no less intense colds of Terra del Fuego, and other stony countries in cold latitudes. Thus too, towns being formed of stone or brick, are warmer in summer than the open country, unless the streets be so close as to intercept the sun's rays, and *vice versa.*

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[*] Dr. Harrington.

LETTER XVIII.

FROM the atmosphere and its properties, we next pass on to other aeriform fluids, of equal importance in the sublime operations of nature. There is not any thing within the knowledge of man more wonderful, than the respective and peculiar energies of air; nor can any thing yield matter of more admiration, or of more profound contemplation, to a philosophic mind. The changes which bodies undergo by means of these fluids are astonishing. We even see solid, hard, opaque bodies almost entirely reduced into a substance, which possesses properties totally different; *— a fluid, transparent, invisible, whose particles, instead of their former attraction, shall now repel each other so forcibly, that the utmost force of mechanical pressure shall not be able to form them again into a solid. On the other hand, elastic, invisible fluids, shall lose at once their aerial form, and be concentrated by the means of some other substance; nay, two fluids which, by themselves are invisible and elastic, shall,

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* Nicholson.

when mixed together, lose their elasticity, and become a body both visible and tangible, a salt.

The kinds of air, which in general appear to be essentially distinct from each other, are fixed air, acid air, and alkaline air;* for these, and another principle, which it has been impossible to exhibit in the form of air, and which has never yet been exhibited by itself in any form, seems to constitute all the kinds of air. The terms, therefore, in common use, and agreeable to the common nomenclature, are, atmospheric air, fixed air, mephitic air, and inflammable air. The last indeed is particularly characterized, as it takes fire, and explodes on the approach of flame. As to the term mephitic, it might be as well applied to that which is called fixed air, as to that which is inflammable, and to many other kinds; since they are all equally noxious when breathed by animals. Besides this, there is the dephlogisticated or vital air.

The following table, however, will exhibit the specific and distinguishing weights of the same quantity of different airs.

Phlogisticated,

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* Priestley

	dwts.	grs.
Phlogisticated,	7	15
Nitrous,	7	16
Common,	7	17
Dephlogisticated,	7	19

From this it appears, that nitrous air, and air diminished by phlogistic processes, are rather lighter than common air; and that dephlogisticated air is heavier than common air. The levity, again, of inflammable air is excessive, it being ten times lighter than that of the atmosphere. Thus, the purer air is, the heavier it is; the more phlogisticated, the lighter.

Permanently elastic fluids are transparent, and by themselves invisible. All are incapable of assisting combustion or animal life, excepting common and dephlogisticated. These two last likewise, together with inflammable and nitrous air, are with difficulty, and in small quantities, absorbed by water. Fixed air is in a great quantity absorbed, bulk for bulk almost. The other airs, such as vitriolic acid air, nitrous acid air, fluor acid air, and the alkaline air, are in great quantities almost entirely absorbed by water.* The elastic fluids, however, hitherto

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* Cavallo.

discovered, with the principal various names given them by different authors, are those that follow, excepting only a few, which have been very imperfectly described. 1. Atmospherical or common air. 2. Fixed air, or aerial acid. 3. Inflammable air. 4. Nitrous air. 5. Dephlogisticated air. 6. Vitriolic acid air. 7. Marine acid air. 8. Nitrous acid air. 9. Fluor acid air, or sparry air. 10. Alkaline air. These are also, excepting common air and dephlogisticated air, called *gases*, with their distinguishing epithets, as *inflammable gas*, &c.

The atmospheric air we have already considered. We shall now, therefore, inquire into the aerial acid, or fixed air. This air had been observed on the surface of fermenting liquors, and was called *gas* (the same as geist or spirit) by Van Helmont and other German chymists:* but, it afterwards acquired the name of fixed air, when it was discovered, by the celebrated Doctor Black, to exist in a fixed state in alkaline salts, chalks, and other calcareous substances. There are, in fact, few substances in nature that do not contain fixed air, discoverable either by heat or by some stronger acid. It is always contained in common air; and also in the purest dephlogisticated

* Priestley.

cated air. It is only a peculiar acid in a state of vapour, which modification it assumes on its expulsion from bodies, by the power of a superior acid taking its place. It is an elementary substance; whereas common air is a compound. Joined with phlogiston, indeed, it may serve to form the latter. However this be, as I have just observed, all fermented liquors that are not quite flat or vapid, contain fixed air. The result of experiments on the subject is as follows.

The air contained in an equal quantity of the following fluids,

In Madeira, - - - - -	$\frac{1}{100}$ part of an oz. meas.
Port of 6 years old,	$\frac{1}{48}$
Hock of 5 years	$\frac{1}{24}$
Barrelled Claret,	$\frac{1}{12}$
Tokay of 16 years,	$\frac{1}{20}$
Champagne of 2 years,	$\frac{2}{3}$
Bottled Cyder of 12 years,	3 parts and $\frac{1}{4}$.

This fixed air has been ascertained by Mr. Cavendish to be 1½ heavier than atmospherical air. He has also ascertained, that water, being impregnated by it, will dissolve iron, and thereby become a chalybeate.

This aerial, or carbonic acid, is found either in an aerial state, as in mines, caverns, wells, or combined with water, in mineral, or common springs; or combined with absorbent earths, or in ores. It is known by its properties of extinguishing lights, uniting to water, and then precipitating lime water.* The *vitriolic*, when dephlogisticated, is always united to water, and as in the earth it must meet with bodies with which it is capable of combining, I believe it has never been found free from combination. The *phlogisticated*, or sulphurous vitriolic acid, frequently occurs in a free aerial state, bursting from volcanic mountains, and also in some caverns and mineral waters. The *nitrous*, called *aqua fortis*, though generally ranked among the mineral acids, can scarcely be called so, as it always requires for its formation the putrefaction of animal or vegetable substances. It is never found disengaged from all bases (except perhaps in charnels and the repositories of animal excretion) but always united either to alkalis or earth. The *marine*, or muriatic acid, frequently named spirit of salt, is found only in a state of combination with alkalis, earths, and some metals. The *sparry* is found in fluor spar, lapis lazuli, chrysopasium, and phosphoric blende. The *succinous* is found only in amber. The *phosphoric* has as yet been discovered only in fossil bones, and in one species of lead ore. It probably owes its origin to a decomposition of bones. The *molybdenous* being very lately known, has been found only in molybdena. The *arsenical* has been traced in the ores of other metalic substances, particularly of cobalt. The *tungsten* has hitherto been found only in the calcareous stone called tungsten.

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* Kirwan.

The bodies thus called *acids*, are combinations of vital air, with a certain elementary substance. The analysis of almost all the acids, whose component parts are known, establishes this truth in a positive manner; and it is on account of this property that the denomination of oxigenous gas has been given to vital air. The word *sour*, which is usually employed to denote the impression, or lively and sharp sensation, produced on the tongue by certain bodies, may be regarded as synonimous to the word acid. The only difference which may be established between them is, that the one denotes a weak sensation, whereas the other comprehends all the degrees of force, from the least perceptible taste to the greatest degree of causticity. We say, for example, that lemons are sour; but the word acid is used to express the impression which the nitric, sulphuric, or muriatic acids make upon the tongue. The causticity of acids appears to arise from their strong tendency to combination: and it is from this property, that Newton has defined them to be bodies which attract and are attracted. It is likewise from this property, that certain chymists have supposed acids to be pointed substances. On account of this decided tendency also to combination, it seldom happens that they are found in a disengaged state. With alkalis acids they generally effervesce, but not always. Thus, the carbonic acid, and almost all weak acids, cannot be distinguished by this property; and the purest alkalis combine with acids, without motion or effervescence. In regard to *alkalis*, it is usual to call any substance an alkali, which has an acid, burning, urinous taste; the property of converting syrup of violets, green; the virtue of forming glass when fused with quartzose substances; and the faculty of rendering oils miscible; of effervescing with certain acids; and of forming neutral salts with all of them. The alkalis are divided into fixed and volatile. This distinction is established upon the smell of these substances: the former are not volatilized, even in the focus of burning mirror, and emit no characteristic smell; whereas as the latter are easily reduced into vapour, and emit a very penetrating odour.

But as we have already observed, fixed air enters universally into the composition of all animal substances, and is of so extraordinary a nature, that it may be made the instrument either of health or of disease, of life or of death.* For instance, if an animal be immersed in a sufficient quantity, a total loss of sense and motion immediately ensues; and if the animal be not speedily returned into common air, death is the certain consequence. On the other hand, when properly managed, it promises salutary effects in some instances, and may be variously adapted to the purposes of medicine. It may be externally applied, either by a proper apparatus determining it upon the diseased parts, or by mixing it with the air of the chamber, so as to be freely and constantly respired.

The cohesion and solidity of substances are, in the opinion of Macbride, owing to the fixed air they contain: and, when by any means this is taken away, the mutual adhesion of the several parts will be destroyed, and the body will either run into the putrefactive fermentation, or crumble into dust, according to the nature of its constituent parts. Hence it necessarily follows, that whatever substance has the power of impeding the separation of fixed air, or of restoring it when separated, will also prevent or correct putrefaction. A piece of flesh, for instance, surrounded by a substance of this kind, is kept sweet, because the fixed air cannot make its escape, and that, probably, on account of its pores being blocked up by the finer particles of the antiseptic matter. If it has already, however, become putrid, it will receive fixed air from the antiseptic body, and hence cease to exhale a fœtid smell, lose its fluidity and flabbiness, and at last recover its sweetness and firmness.

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* Dobson.

The power of this aerial acid, you thus perceive, is very great; it preserves and it destroys. But, there is one thing very singular regarding it, which is, that if an animal be plunged into a sufficient quantity of it, he will instantaneously expire, and without a convulsion. Now why this should be the case is uncertain, unless the system of an animal, or its vital principle, be of the nature of the electric matter, which is in a similar manner, and with equal expedition, swallowed up and dissipated by it. Thus we see that not only grottoes and caves, but that even waters themselves are sometimes so strongly impregnated with fixed air, as to kill frogs and fishes of every kind. "Ranas nimirum, cancros, pisces quoscunque, in his aquis incontinenter mori." And hence the probable utility of fixed air in vermicular diseases, as recommended by Dr. Hulme. As it deprives an animal of existence, so it effectually prevents fire from being kindled, and combustible matter from explosion; it even completely and instantly extinguishes a body red hot and flaming; so that to determine the presence of this mephitic fluid by flame, is a common experiment. In some places the poisonous stratum of fixed air has a very inconsiderable depth indeed. In the Grotto del Cane near Naples, men, and even large dogs, as you have seen, suffer nothing while they stand erect; but if the nostrils of any animal be brought near the ground, it is instantly seized by stupefaction. This deadly vapour may be seen, like a very subtile smoke, which in summer rises about a foot from the ground, but in winter not above a few inches.*

Feeling the benefits, however, of fixed air, as well as its deleterious qualities, philosophers conceived hopes, that it might be rendered of the most decided utility to mankind. Sir John Pringle among the rest, and with great probability, supposed, that the great abundance of it contained in vegetables and saccharine substances, and which at this time make up a considerable part of the diet of European nations, was the cause of the prevention of those putrid diseases and plagues, which were in former days so very prevalent. Fixed air most assuredly has the power of sweetening the putrid effluvium. It has indisputably an antiseptic power. It may be said to be demonstratively certain, that it destroys the putrefactive fermentation. " Hence, (says Priestley) the use of wort and other substances, which contain fixed air, and yield a great quantity of that fluid in the stomach, are strongly recommended in scorbutic cases. Administered, or taken internally as medicine, they have been found of prodigious service in putrid disorders. Men in the sea scurvy are cured by being buried partially, or up to the necks in fresh earth, and this is owing to the absorption of the fixed air by the pores of the skin. Following the plough is also an old prescription for a consumption. Fresh mould takes off the foetor from meat beginning to putrify.

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* Bergman.

Still pursuing the idea of fixed air being all powerful in its operations, the experimentalists, who indefatigably, and with noble emulation, strove to increase the number of its benefits for the good of their fellow creatures, imagined it might be beneficial in the cure of that racking disease the stone. " So strong is the relation," says Priestley, " which subsists between mephitic or fixed air and water, that they remain firmly combined, and so rush into the urinary organs; hence a salutary medicine for the stone or gravel, preferable to, and more pleasing than lime-water, which nauseates, destroys the appetite, and creates a disagreeable sensation; or soap-ley, which is caustic and acrimonious; which often produces sanguinary urine, and aggravates the torture which it is meant to relieve." When combined with an animal earth, indeed, fixed air was supposed by some to form the stone and gravel.* Bergman thought that the acid of sugar, together with an animal gluten, constituted the urinary calculi; to these however, observed other physicians, a calcareous matter must be added, as may be inferred from the effervescence and indissolubility of many of them in the vitriolic acid. The air found in the stomachs of animals is mostly of the fixible kind; but that in the intestines is generally inflammable.

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* Dobson,

Notwithstanding these flattering prospects of the efficacy of fixed air, a very able and accurate philosopher has assured Dr. Percival, that, unfortunately, in opposition to the opinion of its being beneficial in the stone, the calculi which he has tried have universally resisted the action of mephitic water. And he further adds, that not one of them has been found to contain a single grain of absorbent earth, but that all of them have proved inflammable like gall stones. Dr. Heberden has asserted the same thing. But, on the other hand, (and thence there are some hopes still remaining) it has been fully shewn, that these substances vary in their structure and composition; and that calcination converts some into quick-lime; that others are consumed entirely in the fire; and that a third sort yield, after burning, an insipid residuum, incapable of giving any impregnation to water.* "On this subject," says Scheele, "I conclude, a calculus is neither calcareous nor gypseous, but that it consists of an oily salt, in which the acid prevails a little, since it is soluble in pure water, and imparts to the tincture of lacmus a red colour."

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* Falconer.

lour." That it contains phlogiston, appears by its solution in caustic alkalis and lime water.—"I have found calculi also," says he, "dissolved in all urine, even in that of children. All urine contains some animal earth, or lime combined with phosporous acid, and by the superabundance of acid this earth is kept dissolved. It is remarkable, that the urine of the sick is more acid, and contains more animal earth than that of healthy persons.

"But are we not, in truth, to consider the stone," says Dr. Falconer, "sometimes as a disease of the constitution? Is it not, in some instances, rather an animal production, than proceeding from stoney matter introduced *ab extra*, and afterwards collected and concreted? Does not the oyster, for instance, furnish by its own peculiar œconomy a large mass of calcareous earth, which serves it for a substantial covering and defence? And is not this the product of a peculiar organization? Is not another analogy to be deduced from stoney matter, which incrusts the teeth of the human species themselves?"

The carbonic acid, or fixed air, is found in three different states; in that of gas, in a state of mixture, and in a state of combination. It is found in the state of gas at the Grotto del Cane, near Naples, and in a variety of other places; in tombs, cellars, &c. It is disengaged in this form, by the decomposition of vegetables heaped together by the fermentation of wine or beer, by the putrefaction of animal substances, &c. It exists in the state of simple mixture in mineral waters, since in these it possesses all its acid properties. It exists in a state of combination, in lime-stone, common magnesia, alkalis, &c.

LETTER XIX.

AS fixed air was ascertained to be highly pernicious, in certain instances, to the animal system, so it was likewise very generally believed to be fatal to vegetable life. Dr. Priestley thus having kept the roots of several plants in water, impregnated with the carbonic acid, observed they all perished; and in those instances where plants are observed to vegetate in water, or in air, which contains this gas, the quantity of gas is very small. M. Senebier has even observed, that plants which are suffered to grow in water, slightly acidulated with this gas, emit a larger quantity of oxigenous gas; because, in this case, the acid is decomposed, the carbonaceous principle combines, and is fixed in the vegetable, while the oxigene is thrown off. But the validity of this opinion has lately been doubted by a very accurate and able experimentalist.

" Fixed air," says Mr. Henry, " is now generally allowed to be formed by a combination of phlogiston with the pure part of atmospheric air."

air." Dr. Priestley and others insist, that the first of these ingredients is favourable to vegetation, while plants droop and decay, when exposed to the action of the latter. But why may we not suppose, that though fixed air, when pure, may be fatal to plants confined in it, and excluded from free communication with the common air, yet when applied in proper quantities, and to plants enjoying a free intercourse with the atmosphere, it may have a contrary effect, and serve to nourish and support them? From Dr. Ingenhouz's experiments, it appears that plants have the power of separating phlogiston from common air, applying it to their nature, and throwing out the pure, or dephlogisticated residuum, as excrementitious. Now, allowing what appears very probable, that they have a similar power of decomposing fixed air, and of applying and rejecting its constituent parts, fixed air may be equally nutritious to them. Confined, indeed, in close vessels with fixed air, plants must perish. In the same manner as from a want of communication with the atmosphere, as necessary to carry off the phlogiston thrown out from the lungs, an animal must perish, so in the instance of a vegetable, the plant must die, if cut off from the air of the atmosphere in such manner, that the pure air excreted by its vessels, cannot be conveyed from it. For in these circumstances this fluid of pure air, so salutary to animal life, but destructive to vegetable existence, must be accumulated in the body of the plant; and its functions being thus impeded, death will be the necessary consequence.

This reasoning seems ingenious, and probably may be just; but as it militates against the doctrine generally established, of fixed air being hurtful to vegetation, I shall leave the examination of it to more able hands, and here content myself, with a point which to me, at least, appears less questionable. Vegetables both meliorate and injure air: nor are either caused by heat or by vegetation; but merely by the presence or the absence of the *solar light*. In the day and in the light, they meliorate the air, though heated by artificial means, they yield a pernicious effluvium, and operated upon by electricity, are only affected by the mechanical impulsion; whereas, in the absence of light, they shed a mephitic influence. Thus, in the first instance, we have the *pabulum vitæ*; in the second, the the *pestis vitæ*. A dephlogisticated air is found to be spread around vegetables in the sun; a phlogisticated air in the absence of the sun.

No poison is more subtile than the air which is left after respirable air is destroyed. The œconomy of vegetation, in these particulars, is astonishing; and there is no subject which has been more industriously or successfully attended to by philosophers. Ingenhouz was the first who proved the great truth, that plants, when exposed to the influence of the light of the sun, correct the vitiated air caused by the breathing of animals, and other phlogistic processes; but that placed out of the influence of the sun, they infect the air so as to occasion the extinction of life; a single plant being capable, in the course of one night, of rendering a body of mephitic air of fifty times its own bulk. Vegetables commence their wholesome task shortly after the sun has risen above the horizon. It is then, that having shaken off the drowsiness and lethargy of the night, they begin in plentiful showers of vital air, to correct the nocturnal air which has become vitiated. This operation of plants is more or less vigorous according to the brightness of the day, and the situation of the plants, in regard to the direct rays of the sun. When shaded by buildings, or by other means, their exhalations, so far from being serviceable to the animal œconomy, are, on the contrary, essentially poisonous. The stream of good air begins to subside towards the close of the day, and ceases, in general, entirely after the sun is set.

In the elaboration of this pure air, or in the elaboration of the mephitic air, all the parts of the plant are not engaged. The leaves, the roots, and the branches, are those parts alone which are employed. In general, the pure air is poured from the inferior surface of the leaf. But young leaves, and those that have not acquired their full growth, do not yield either so great a quantity, or of so good a quality, as those which are of their full size, or which are even old. All leaves are not equally bountiful; many of the aquatic genus are found to be the most liberal; nor are all leaves equally pernicious during the night and in the shade. Some, however, which do not yield to any in their diurnal operation of producing good air, surpass others in their power of infecting the common air during the night and in the shade, insomuch, that in a few hours they can so corrupt a great mass, as that it shall give almost instantaneous death to an animal plunged into it.

Flowers, particularly roses and violets, always exhale a mortal air, and vitiate the surrounding mass, both day and night, both in the light and in the shade. Inclosed with atmospheric air, they generate a dreadful poison. This their mephitic emanation, however, is quite different from the emanation which is their perfume. The first is as much to be apprehended, as the other is innoxious and agreeable. Roots recently taken out of the ground, have, in general, the same deleterious qualities as flowers. Fruits, even the most delicious, are equally pernicious. Peaches, like flowers, for one night, in a small confined bed-chamber, would so poison the air, as to destroy any person who would venture to sleep in it. Mushrooms exhale at all times a mephitic air; they are always surrounded by a poisonous atmosphere. Sickly plants lose their faculty of elaborating wholesome air; though they retain their faculty of generating mephitic air.

As the heats of summer decrease, both leaves and fruits grow feeble in their mephitic operations during the night and in the shade. The nocturnal emanations of leaves, and continual evaporations of flowers and of fruits, do not diminish in quality in winter, they only diminish in quantity; and this seems apportioned to animal wants, for animal respiration is less vitiated in winter than in summer. Evergreens lose in winter almost entirely their faculty of meliorating common air, but preserve the power in the sun, of correcting the air that is contaminated by respiration, and by other phlogistic processes. The faculty in vegetables of giving pure air in the sun, and bad air in the shade, augments towards the spring, according to the vigour of vegetation. The diurnal emanation from leaves is simple; it is a pure, or a dephlogisticated air, without any mixture of fixed air; but the nocturnal is a compound of fixed air, and of phlogisticated or inflammable air. Notwithstanding all this, we have no reason to complain, that common air is not vital air. If it were, we should undoubtedly respire better, but all the vegetable world would perish. And, on the other hand, were it more loaded with phlogiston, plants would vegetate better, but all animated nature would perish. The bounty of Providence has wisely established a medium by which the existence of both is maintained. In all the surprizing elaboration of these fluids, the leaves are the principal instruments; the varnished superior surface imbibes the essential particles, which, after elaboration, are by the inferior poured forth in pure but invisible streams. While the heats of summer prevail, and there is consequently a tendency to corruption, these streams are the most plentiful. In the winter, when the cold stops this general tendency to corruption, the leaves, being no longer of use, fall off. In the spring they again appear. Thus leaves have a function, which, independent of their beauty, should make us look upon them as kind co-operators in the preservation of animal existence. The mephitic, or phlogistic emanations, which they exhale in obscurity, are lighter than the general mass of the atmosphere, and consequently ascend and leave the inferior regions in purity. Hence, the atmosphere is as good during the night as during the day; and hence, at least in our temperate climates, the atmosphere is best in the height of summer and in the height of winter; for in the first, the vegetable world is in its greatest vigour; and in the second, the general tendency to corruption has ceased. I have wandered, however, a little too far from the point we were engaged upon, the universality of the aerial acid, or fixed air.

To return therefore to our main subject; the genuine mineral spirit which gives character and life to cold mineral waters, has at length, by incontrovertible experiments, been shewn to be altogether the same with fixed air. It is the principle which is common to the Seltzer, Spa, and Pyrmont waters; though different salts, in different proportions, determine the different species of these waters. Hence water, by bare impregnation with fixed air, cannot properly be called either of them.* The elastic fluids, indeed, extracted from mineral waters, are commonly said to be three; namely, fixed air, inflammable air, and phlogisticated air. Sometimes one or two, and sometimes even all three are found together in the same mineral waters. In some instances, however, they are so loosely mixed with the water, that by mere exposure to the open air, they escape in a short time; while on the contrary, in other cases, a very long boiling is hardly sufficient to expel them. But besides these, very minute particles of flint, lime, magnesia, and clay, are sometimes found mechanically suspended in water. The argillaceous particles obscure its transparency, and render it of an opal colour: the others occasion variations which are less observable, because the subtilty of their particles, and the surrounding waters, render them transparent. But various substances are found united with water, and with each other more intimately, that is, by means of chymical solution. Pure air is contained in most waters. *Aerial acid* is found in *every* water. Inflammable air sometimes issues from waters. The other acids are only in a disengaged state, found in waters accidentally; as for instance, the sulphurous acid in the mephitic waters, which have the property of discolouring silver. Vegetable alkali is seldom found in waters; mineral alkali often; volatile alkali sometimes; terra ponderosa sometimes; lime frequently; magnesia not so frequently. Vitriolated clay, or alum, is rarely found; muriated, or salited clay, sometimes. Among the metals, iron is more frequently discovered in waters. Manganese has not yet been found. Copper has only been found vitriolated; arsenic, very rarely. Water is sometimes contaminated with extracts from animal and vegetable substances. "I could not, however," says Bergman, "discover any certain signs of bituminous oil, it being immiscible with water, unless by means of an alkali." Petroleum, agitated with distilled water, separates again upon standing. It must be acknowledged, however, that the water, even after the most careful filtration, still retains a strong bituminous smell. These heterogeneous matters are never found all together, but are more or less numerous in different waters. Thus some of them are contained in atmospheric waters; others in those found on the surface of the earth; and finally, others in sea water.

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* Bergman.

This enumeration of the extraneous substances discovered in mineral waters, would, with more propriety, perhaps, have found its place, when the element itself of water shall be brought before us. But it was difficult to separate what so perpetually are seen blended. Fixed air is always found in water, and hence, though in less proportion in some than in others, it universally must be looked upon as an invariable attendant, though not as a constituent part of the fluid of water. From fixed air, therefore, which, blended with inflammable air, was erroneously at first supposed to constitute common air, we shall proceed to a consideration of what is termed the phlogisticated air.

We have already, and pretty much at large, entered into the subject of fire; but whether it be a fluid of a nature peculiar to itself, which was created such as it is, and cannot be altered in its nature or properties, destroyed or produced; whether it be generated or let loose by motion and collision; or whether it passes to us in a palpably heated state from the sun; it is generally admitted, by at least the old chymical school; that, besides the fluid fire, universally diffused, there is a fire which enters in different proportions into the composition of all animals, vegetables, and most minerals; and in that condensed, compacted, fixed state has been deemed *phlogiston*. Thus, says Priestley, "there is no animal or vegetable substance whatever, nor any mineral substance that is inflammable, but what will yield a great quantity (of this phlogiston), as inflammable air, when urged by a strong heat. This air kills animals as suddenly as fixed air, and, as far as can be conceived, in the same manner, throwing them into convulsions, and thereby occasioning death. The composition, indeed, of this inflammable air seems chiefly, if not wholly, to consist of the union of an acid vapour with phlogiston." * Water, it is probable, always contains a certain portion of it; for by agitation in water, it loses its inflammability, so as to be fit for respiration. Of all bodies, however, it is one of the most combustible in nature, and yet it will not burn without the contact of other air. The finer the air, the greater its rapidity; and consequently it is the most violent in dephlogisticated air.

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* Priestley.

This very subtile matter of phlogiston admits, like the aerial acid, of two states, a state of combination, and a state of freedom.* In the former it enters into the structure of bodies, eludes all our senses, and can only be recognized by its effects; for which reason, some have supposed it to be a fictitious substance, and totally impalpable, but, probably, without reason. Priestley and Kirwan have, to their own satisfaction, demonstrated its existence, both analytically and synthetically. This principle, when in combination (and then it is properly called phlogiston) may be set loose by various methods: having recovered its elasticity, and gained an aerial form, by a proper increase of specific heat, it receives the name of inflammable air. Phlogiston is perhaps to be found in all bodies, though in many it is concealed by its exility. The quantities of it, however, to be acquired from certain substances are prodigious.

An ounce weight of lead contains 100 ounces measure of phlogiston.

Ditto of tin - - - - - - - - - - - 377 ditto
Ditto of copper - - - - - - - - 403
Ditto of blue vitriol of copper - 909

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* Bergman.

An ounce of bismuth - - - - -	185
Ditto of iron - - - - - - - - - - -	890

In contradistinction to the pernicious qualities of this air, of which we shall treat more fully hereafter, there are two others, which, though in dissimilar ways, are yet of considerable importance; I mean, dephlogisticated and nitrous air. The latter, indeed, is the phlogiston of copper, generated by the nitrous or vitriolic acid and copper, and being established as the test or criterion of all other airs, is called the *trial air*. This air, however, though highly noxious to animal and vegetable life, is yet in its deleterious qualities, apparently counterbalanced by its remarkable property of hindering putrefaction; so that several substances may be preserved in it uncorrupt for a considerable time. After long keeping, it is true they become offensive * both to the scent and to the palate, though the smell is not altogether that of putrefaction; and, indeed, the substance continuing quite firm, it could not be properly putrid. "Nitrous air," says Priestley, "consists of the nitrous acid vapour, united to phlogiston; together, perhaps, with some small portion of the metallic calx. It not only preserves substances, but restores those that are already putrid, and that in a far greater degree than fixed air. It is to be procured not only from copper, but from all the perfect metals, by spirit of nitre, lead excepted; and from all the semi-metals, zink excepted. Long exposed to a large surface of iron, it has the most deadly consequences. Animals die the moment they are put into it, notwithstanding a candle will burn in it freely at the same time." "In regard to nitrous acid," says Bergman, "it may be conjectured that, in small proportions, it is a constituent part of dephlogisticated air, or that phlogisticated air is nitrous acid, with a larger proportion of phlogiston than nitrous air." To the latter supposition Mr. Cavendish also evidently inclines, and observes, in conformity to it, "that part of the phlogisticated air, with which the vital air is debased, is, in his experiment, converted into nitrous acid, by the strong affinity of the latter to phlogiston. The common office of nitrous acid is merely to dephlogisticate water.

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* Nicholson's Philosophy.

The other important air which I mentioned above, the dephlogisticated or vital, is of so great consideration, as to have amply requited the pains which have been taken towards its investigation. Some deduce it from the dephlogistication of the aerial acid; Scheele from the decomposition of heat. One circumstance, however, relative to it is certain, that there is no place upon earth yet discovered, where it is found naturally, like fixed or inflammable air, though it is to be obtained from certain substances, by various processes. In the works of some old authors, some faint ideas are to be found of an elastic fluid purer than common air,* especially in some tracts of Dr. J. Mayow, which were published at Oxford in the year 1674; but their notions, however to be admired, were not only unsupported by decisive experiments, but were exceedingly confused, and so involved in conjecture, that they can hardly be supposed to have afforded any light to the modern philosophers who have discovered that admirable elastic fluid, and have ascertained many of its interesting properties. Priestley was the first who discovered it in this country, and from its containing a very small share of phlogiston, distinctly identified it by the appellation of dephlogisticated air. At the same time, Scheele, of Sweden, was labouring, and as effectually, towards the like discovery. Ignorant of each other's views and experiments, these able men strove to attain the same great end, and separately atchieved it. Both the one and the other, therefore, are entitled to the honour of the discovery. Scheele called the pure elastic fluid he discovered *empyreal air.*

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* Cavallo.

Dephlogisticated air may be obtained from all sorts of substances, whether vegetable, animal, or mineral, when mixed with nitrous acid, and exposed to a sufficient degree of heat, provided those substances be first deprived of phlogiston. From some, indeed, more of it can be obtained than from others, as metallic calces, and calcareous earth. In short, substances of every sort, when mixed with nitrous acid, and acted on by a sufficient heat, produce an elastic fluid, which, if it contains much phlogiston, is nitrous air; if the quantity of phlogiston contained is very small, it is fixed air; and if the substance is very much dephlogisticated, the produce is pure dephlogisticated air. The purity of this air is abundantly striking. It takes up a greater quantity of phlogiston than any other air, and is consequently the longest fit for animal respiration. "It is, in a word," says Priestley, "five times as pure as common air; animals will live in it five times as long; a candle will burn in it with five times as much lustre; and inflammable air fired into it will report many times louder than in common air." A very remarkable circumstance, however, attending this air is, that the calx, for instance, of a metal, whence it shall be derived, is heavier than the metal itself. Thus one hundred weight of lead turns out one hundred and twelve weight of calx. The metal, during its calcination, draws from the general atmospheric stock a great abundance of this purer fluid, which it greedily imbibes, and preserves in a concrete form. The calx, which contains the most dephlogisticated air, is that of quicksilver, commonly known by the name of red precipitate.

In our enquiries into fixed air, one of the substances most plentifully yielding it, we established, on good authority, to be calcareous earth. But Mons. Bertholet says, "that no aerial acid is disengaged, but only atmospheric air, which gradually becomes more and more pure, and is at last very pure dephlogisticated air." "A problem, however," observes Bergman, "which, though highly worthy of it, has not yet been sufficiently investigated." But, be this as it may, the very great purity of the dephlogisticated air rendered ingenious men desirous of turning it to that end, by which alone discoveries are made respectable, the good of mankind. Accordingly it was conceived, that in those fatal diseases of the lungs, which several climates abound in, it might be particularly beneficial.[*] "Persons affected with those disorders," said they, "are often conveyed into distant places for the sake of breathing a kind of air, which, at most, is very little better than the air of their actual dwelling places; whereas, by using this artificial air, they might save the inconveniencies of travelling, and breathe an elastic fluid incomparably better than the air of any country upon earth."

Pure dephlogisticated air, which possesses both a fixed fire and an acid, agreeably to Lavoisier, it is certain, might be of utility as a medicine;[†] but it is natural to believe it would be pernicious for the body in health; for as a candle burns out much faster in dephlogisticated than in common air, so it may be inferred that the animal powers would be too soon exhausted in so pure an atmosphere, and that we should *live out too fast.* Moreover, it is certain that animals will not live in dephlogisticated air, as they will in atmospheric air; that is, until they have completely phlogisticated the whole aerial fluid. I have already mentioned the deleterious powers of the fixed air. In addition, however, to what

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[*] Cavallo. [†] Priestley.

I have said, it may not be amiss to tell you, that the *volatile alkali*, applied to the nostrils; or mixed in water, poured down the throat, has been known to restore life to a man who was supposed completely suffocated by the acid vapour of charcoal, which is nothing but fixed air; as it has been known to bring back life to another, who was suffocated by the vapour of the vinous fermentation. Apoplexies have even been cured by it. Boerhaave says, that once, being deeply employed in an experiment, an acid vapour seized upon the vital powers, and that he should infallibly have died, had he not had an alkaline spirit close at hand, which he immediately applied to. In less alarming, but really dangerous emergencies, it has been found of efficacy, particularly in excess of intoxication. A man totally bereft of his senses by drink, has been rendered sober by having twelve or fifteen drops of this alkali, mixed in water, poured down his throat. The pain of burns, which is chymically supposed to be caused by the action of the igneous acid, is instantly mitigated by the application of alkalis: even a *coup de soleil* is to be counteracted by the external application of one part of volatile alkali, blended with eight or ten parts of water; and by the internal application, as I have said above, of twelve or fifteen drops mixed in water.* This is worth remembering. In regard to nitrous air, as we have above seen, it has long been known to have the property of preserving bodies; but, in regard to phlogisticated air, it was not until Mons. Charles discovered it, that that inflammable gas was proved not only to have the property of extinguishing life, but also of *dissolving* the animal texture. Here then, may we not ask, in the words of Sage, if this inflammable air, which we inhale from the atmosphere, does not serve, in some manner, to dissolve the aliments of animals, and to turn them properly into attenuated and nutritious chyle?

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* Sage.

LETTER XX.

FROM the general glance which we have thus cast upon the principal of the permanently elastic fluids, we have been enabled, at least, to establish a conviction of their very high importance in the general chain of terrestrial nature. But there are yet more familiar lights, in which they are to be placed; I mean the powerful and uniform effects which they have upon the animal and vegetable, as well as upon inanimated nature. Under this view, therefore, we shall again, for a moment, consider them.

Plants and animals, as I have already said, act reciprocally on air, for each other's advantage; the breath of animals corrupts the air; the air so corrupted becomes more nourishing to plants; and the respiration observable in plants, is the reverse of that in animals. * The latter take in pure air, and send it out foul and phlogisticated. Plants take in this foul air, and return it purified; and this is simply analogous to their faculty

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* Philosophy of the Elements.

culty of elaborating sweet juices from impure earth and manure. The sun raises a pure air from plants; whence the atmosphere in the day-time is rendered more wholesome than in the night; for plants in the night, or in the shade, have a contrary effect upon the air; but their bad effect in the night is not nearly so great as their good effect in the day. Flowers always hurt it both day and night. Water plants are remarkably vigorous in their faculty of yielding pure air to correct the inflammable air, which is bred by the soil in low marshy grounds. Thus the best remedies are produced, in every region, for its native evils; and thus do all things work together for the general good.

" The effluvia of human bodies," says Arbuthnot, " and the same in some degree of other animals, are extremely corruptible; and so is the water in which people bathe, by retaining cadaverous particles. Less than three thousand human creatures, living within the compass of an acre of ground, would make an atmosphere of their own steams, about seventy-one feet high, which, if not carried away by the winds, would turn pestiferous. Owing to this circumstance, the air of prisons often produce mortal diseases; and ships crews turn sickly in bays and harbours, who would be healthy in the open seas.

That the air which passes from the lungs is highly mephitic, is easily proved, by breathing five or six times into a glass vessel, and by then putting a lighted candle into it, the candle will instantly be extinguished; but introduce a fresh plant into the vessel, and then immerse the vessel in water, so as that the newly generated air shall not escape, and it will be so altered, as to be rendered thoroughly pure and wholesome, and, of course, the candle will burn in it with the greatest freedom. The manner in which phlogiston thus taints air, may be in this familiar way exemplified. A lighted taper placed under a glass, or other close cover, will preserve its flame, until the interstices between the particles of the enclosed air shall be saturated with the phlogistic matter, and shall be capable of containing no more. In like manner, if a lighted taper under a glass cover be immersed in water, the flame will continue in vigour, until the surrounding air shall begin to be contaminated by the phlogiston from the taper. It will then gradually die away, and at length go out altogether. And hence the experimentalist, who descends into a diving bell, repeatedly falls the sacrifice to the air which he has breathed. That which passes from himself, he is frequently obliged to inhale, and thus every expiration adds to the mephitic quality of the surrounding fluid, and consequently so loads it with phlogiston, that unless there be a fresh supply of atmospheric or dephlogisticated air, the vital principle will be inevitably destroyed.

Animal effluvia, even from the living body, we thus see, are highly pernicious: when accumulated, and repeatedly respired, they are fatal to the animal œconomy; they diminish the energy of the brain and nervous system, and weaken the action of the heart and arteries. The Count de Milly, of the Royal Academy of Sciences at Paris, undertook various experiments to ascertain the reality of the animal emanations, and at length very satisfactorily proved, that the animal air which issued from his body in a bath, was different from the air of the atmosphere, and had properties that gave it a striking resemblance to what we call fixed air. The pulmonic air, indeed, sent forth by respiration, is nothing else than a mixture of fixed air, diffused through a large quantity of common air, by which the former is carried off, and the pernicious effects of its accumulation are prevented; and this explains the principle of suffocation, and the danger of close crowded apartments, in which the introduction of common air being obstructed, the emanations of fixed air, or animal gas, gain the ascendant. Priestley, however, says, " that it is respiration, and not perspiration, which injures the air." But it seems pretty evident, that both one and the other tend to the accumulation of the mephitic fluid.

Odour, the old chymists said, was an indication of that which modern chymists have proved to be phlogiston. The most delicate flower, as I have already observed, considerably injures air. For instance, nothing is sweeter than a rose, and yet the effluvia from a rose are far from being favourable to the air in which they are confined. In a certain quantity of atmospheric air, the air they would yield would be so noxious, that an animal would immediately expire in it. And hence the odours which arise copiously from bodies, without diminishing their weight, may be supposed to be occasioned, not by an actual diffusion of the substance, but by the modification of the more subtile phlogistic spirit which is continually passing through their pores. But many of the discharges, especially from the surface of the body, and from the lungs, are, even in the most healthy persons, in a state not very remote from putrefaction; but in persons labouring under disease, they are still of a more noxious nature.[*] Nor are we to stop even here. Fresh meat, even without the least sign of putrescency, phlogisticates common air to a great degree, and in a very short time. This inflammable air, or phlogiston, (for, like ice and the vapour of water, they are one and the same substance) is rendered pure and wholesome, by that which, in a state of decay, is equally, if not in a superior degree, deleterious, I mean the vegetable kingdom.

Animal substances have at all times a strong disposition to putrefaction, while the tendency to it in vegetables is slow; and the reason probably is, that the air in animals is mostly inflammable, but that in vegetables fixible. However this may be, it is an indisputable fact, that putrid air is rendered wholesome by the means of vegetation perfectly in health, and the plants growing in situations natural to them.[†] The noxious effluvium, or phlogiston, is in some measure extracted from the air by means of the plants, or the phlogiston of the air unites with their exhalations, and they thereby render the remainder

[*] Adair. [†] Priestley.

remainder more fit for respiration. They, in short, imbibe the superabundant phlogiston; for fluid fire, as well as fluid air, is imbibed by plants in their growth.

In the whole œconomy of nature we in this manner see, that one substance purifies another. Thus fire purifies water. It purifies it by distillation, when it raises it in vapour, and lets it fall in rain; and farther still by filtration, when keeping it fluid, it suffers that rain to percolate the earth.* Animal substances, when mixed with earth, and applied as manure, are converted into sweet vegetables; and putrid substances, mixed with air, may in the same manner be supposed to have a similar effect; but flowers and fruits, we have already observed, and even the roots of plants, when kept out of ground, generally yield bad air, and contaminate the atmospheric air, especially in the night. Yet, the leaves of these plants, while growing, struck by the rays of the sun, are sources whence exhale a continual torrent of pure air, destined to renovate the atmosphere.

Plants, as I have already explained, begin to yield dephlogisticated air a few hours after the sun has made his appearance, and cease, in general, with the close of the day. In a clear day, they yield more than when it is cloudy. It is also greater when the plants are more exposed to the sun, than when they are situated in shady places. From all which it is demonstrable, that the damage done by plants in the night-time, is more than counterbalanced by the benefit they afford in the day-time. By a rough calculation, it has been found that the poisonous air, yielded during the whole night by any plant, could not amount to the one-hundred part of the dephlogisticated air, which the same plant yielded in two hours in a fine day. Plants, in themselves, do not generate dephlogisticated air, they merely filtrate the common air, and separate the phlogiston from it; which phlogiston is absorbed by the plants, and incorporated into their nature. In this operation they do just the contrary of what is performed by animals: they in their vegetation absorb phlogiston from the air; whereas animals, by their respiration, separate the phlogiston from the bodies, and give it to the air. Hence it is that, phlogiston being one of the principal nutriments of vegetables, vegetation is so strong in the neighbourhood of large towns; for large towns, from the number of fires, the breathing of multitudes, and various other phlogistic processes, send into the atmosphere a prodigious quantity of phlogiston, which being afterwards precipitated, or caught by the leaves, gives them a vigour and growth greatly superior to those in the country; of this you may easily be convinced by experiment: for, put two vegetables under glass jars, as nearly alike as possible, and serve the one with phlogisticated, and the other with atmospheric air, the former you will find shall be strong, healthy, and considerably grown, while the latter shall have lost its colour, be yellow, sickly, and drooping.

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* Priestley.

The very weights of phlogisticated and dephlogisticated airs, as we have already seen, are calculated by nature for our benefit; for the former being specifically lighter, tends directly upwards, and consequently continually recedes from us; whereas the latter, being specifically heavier, as soon as it is yielded by the leaves of plants, tends downwards.* In regard to vegetation, observes Priestley, "It is remarkable, that wells have been injured by being cleansed. The green matter which sometimes is seen to grow on the top of the water, in many instances," says he, "keeps the water sweet, by imbibing the phlogistic matter which it discharges in its tendency to putrefaction. Take that green substance away, and the water will become fœtid, and unfit for use, and will continue so until the sides and top of the reservoir of water shall again grow foul. This was Priestley's idea some years ago, but I do not know that he continues of the same opinion. Many naturalists, as well as he, conceived this substance to be neither animal nor vegetable, but to be merely an aerial or gazous scum. Ingenhouz, however, on the contrary, conceived it to be a vegetable, a species of delicate moss; but they probably all were mistaken as to its real nature. Later experiments prove it to be an animal substance, a mass of scarcely perceptible green animalcula, which have a very short existence, terminated in being clung together by a gluten that seems to exude from their own bodies, and which thus forms the crust on the surface of the water. This production, indeed, is wonderfully to be augmented, by putting any substance into the water which is in a state of putrescency. And in this, we have another striking instance of the wise and stupendous plans of the Creator, who has thus ordained, that in the midst of putrefaction, which has a natural tendency to contaminate the air, a race of beings should be brought into existence, destined to counteract those pernicious effects by diffusing the purest air through the atmosphere. This verdure, or chain of animals, observable on the surface of wells and stagnant pools, was first discovered to be what it is by the Abbè Fontana.

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* Cavallo.

Besides what I have already said of the extraordinary properties of vital air, there is one principle, whose applications are very interesting to be known. In most combustions, the oxigenous gas, agreeably to Lavoisier's theory, becomes fixed and concrete. It therefore abandons the caloric which maintained it in the aeriform state; and this caloric being set at liberty, produces heat, and endeavours to combine itself with the substance nearest at hand. The disengagement of heat is, therefore, a constant effect in all the cases wherein vital air is fixed in bodies; and it follows from this principle, 1. That heat is most eminently resident in the oxigenous gas, which maintains combustion. 2. That the more oxigene is absorbed in a given time, the stronger will be the heat. 3. That the only method of producing a violent heat consists in burning bodies in the purest air. 4. That fire and heat must be more intense in proportion as the air is more condensed. 5. That currents of air are necessary to maintain and expedite combustion. It is upon this principle that the theory of the effects of the cylinder lamps is founded; the current of air, which is renewed through the tube, supplies fresh air every instant; and by continually applying a new quantity of oxigenous gas to the flame, a heat is produced sufficient to ignite and destroy the smoke. On the same principle is likewise explained, the great difference which exists between heat produced by a slow combustion, and that which is afforded by rapid combustion.*

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* Chaptal's Chymistry.

LETTER XXI.

AFTER all that I have advanced on the subject of air, in the style of the old school indeed, but not, I hope, without some degree of accuracy, I still think it necessary to be somewhat more particular on so important a question. Bergman, to whom science is so much indebted, treating of the aeriform fluid, says, "By the term aerial form, I understand such a subtilization of a body, as renders it elastic, pellucid, invisible, light, and permanent, in cold, though not capable of passing through the pores of glass. Vapours, which constitute imperfect kinds of air, are condensed by refrigeration; on the other hand, we have elastic fluids, which may not be improperly stiled *ethereal*; to such neither the pores of glass, nor of any other known body, are impenetrable. To these belong the matter of heat, and the magnetic fluid. The electric fluid easily penetrates all bodies, except electrics *per se*. Moreover, light seems to be something intermediate between aerial and ethereal substances; for it passes through the pores of glass, but not those of metals, and other opaque substances."

We thus see, that the term aerial is not entirely confined to the fluids, which we are endeavouring to investigate. But as these elementary distinctions will more properly occupy our attention at a future moment, we shall still confine our attention to those permanently elastic fluids, generally known by the name of air. In enumerating some of these, we have slightly touched upon the noxious, as well as upon the beneficial airs. There are a few others, however, of the former class, which it is essential to be acquainted with. And in the first instance, let me call to your recollection, that the air in which metals are burned, is at all times highly phlogisticated. For it appears demonstrated, that in the calcination of metals there is nothing more than a combination of the metal with the pure air contained in the atmosphere, which consequently vitiates it. Let me request you likewise, to bear in remembrance, that the air, the most agreeable to animal life; is that which partakes least of sulphur; for sulphur, and all the modifications of it, (at least the aerial) from whatever sources they may arise, whether from minerals under the earth, from marshy grounds,

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or smoaking chimnies, is noxious to the lungs, and will generally have an ill effect on animal respiration. * And hence the reason why charcoal, which, according to Bergman, is nothing but a combination of phlogiston and aerial acid, (99 parts out of 100 being phlogiston) and a species of sulphur, is so greatly pernicious.

"The *hepatic* air," says Mr. Kirwan, "is an actual sulphur kept in an aerial state by union with the matter of heat. It is obtained from combinations of sulphur with alkalis and other substances. Its most obvious characteristics are, a peculiarly fœtid smell; inflammability, when mixed with a certain proportion of common, or nitrous air; miscibility with water in a certain quantity; and a power of discolouring metals, particularly silver and mercury. This air acts an important part in the œconomy of nature. It is frequently found in coal-pits; and Bergman has shewn it to be the principle on which the sulphurous properties of mineral waters depend. There is also reason to think, that it is the peculiar product of the putrefaction of animal substances. Rotten eggs and corrupt water are known to emit the smell peculiar to this species of air, and to dissolve metallic substances in the same manner.

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* Philosophy of the Elements.

Besides these fluids, which have been within these few years discovered, there was always known a factitious air, which lies at the bottom of pits, which is heavier than common air, extinguishes candles, and kills animals that breathe in it, and which miners called *choak damp*.* There is also another factitious air, lighter than common air, found near the roof of subterraneous places, which being apt to take fire, and explode like gun-powder, they likewise called *fire damp*. These, like the others, throw men into convulsions, which weaken and exhaust the vital powers, much more than the most vigorous voluntary action of the muscles; and thus the *vis vitæ* becomes drained.

It has been ingeniously conceived, that one use of the lungs is to carry off a putrid effluvium, without which, perhaps, a living body might putrify as soon as a dead one. The inhaling mephitic air undoubtedly occasions a coagulation of the blood through the whole system; and this of course choaks up the finer, and afterwards the larger vessels, until convulsions ensue, and finally death. It long, indeed, puzzled philosophers, why the blood in going from the heart to the lungs, should be thick and deeply coloured;

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* Priestley.

loured; and that on returning from the lungs to the heart, for the purpose of general circulation, it should be attenuated and florid. Priestley at last found out the cause, and proved it to be owing to a superabundant quantity of phlogiston, which no sooner gets from the heart to the lungs in the blood, than the air of the lungs there disperses and dissipates it. "Without respiration," says Priestley, "animals would die; but the same air will not long answer the purpose; for if it has been frequently respired, the breathing of it is as fatal as the total deprivation of it." Respiration is a phlogistic process. The use of the lungs is to carry off the putrid effluvium; or to discharge the phlogiston, taken into the system with the aliment, the air respired serving as a *menstruum* for that purpose. The blood, indeed, is probably the means by which it is effected, as it is a fluid wonderfully formed to imbibe and part with phlogiston. The redness of the blood is caused by air. Expose it in vacuo, and it is black; re-expose it to the air, and it re-assumes its redness. The blackest parts of the blood, even of an animal, assume a florid red colour in common air, and more especially in dephlogisticated air; whereas the brightest red blood presently becomes black in any kind of air that is unfit for respiration, by not possessing the necessary portion of fixed fire. And hence alkaline salts, &c. applied to the venous blood, will immediately change it to the colour and qualities of the arterial blood. *

Notwithstanding these proofs, Bergman declares, on the other hand, he knows of no experiment, which directly shews that the blood imparts phlogiston to the air. The air he acknowledges to be corrupted; " but that this can only be effected," says he, " by phlogiston, is a mere supposition. On the contrary," he observes, " that by the contact of blood, nitrous air is *dephlogisticated*, and atmospheric air is meliorated." Now, to which side to lean between these celebrated men, it is hard to determine; though it almost incontestably appears, that the vermilion colour assumed by the blood in the lungs, is owing to the pure air, which combines with it; and that a focus of heat really exists in the lungs, which is maintained and kept up by the air of respiration. The phænomena of respiration seem, in fact, to be perfectly analogous to those of combustion. The wisest way, perhaps, is to leave the opposing opinions as they stand, upon their own foundations; and to be satisfied with the conclusion in which they agree, that the air so imparted by the animal system is mephitic. The animal man (and that is sufficient for us here) is supposed to perform fourteen inspirations and fourteen expirations in a minute; that is, he is thought to perform one inspiration for every seven or eight pulsations of the heart; and the mean number of pulsations may be computed at ninety per minute.

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* Dr. Harrington.

When we consider this, and aggregate the quantity from all animated beings; when we consider that a common candle exhausts a gallon of air in a minute; when we consider the amazing consumption by fires and volcanos, the regeneration of it must be conceived enormous. Flame cannot subsist without change of air, excepting in substances into the composition of which *nitre* enters, for these will burn in vacuo, in fixed air, and even under water, as is evident in fireworks; nor without it can animals exist, or vegetables flourish. Fresh air, in fact, is more immediately necessary to the life of *man* (for there are some insects and other creatures that can live, and even delight in the mephitic atmosphere of putrescency) than food; for a man may live two or three days without the latter; but not many minutes without the former. This vivifying principle, so essential to the support of man, and to the support of flame, we have already seen to be the dephlogisticated part of the atmosphere. The common atmosphere, of course, may well be supposed to be more or less healthy, in proportion as it abounds with this animating principle. Hence the fulness of health in the country, where this air exhales, in copious streams, from the green leaves of all kinds of vegetables; and the contrary in cities, where noxious animal effluvia and phlogiston abound. *

Not that this latter idea is to be implicitly, or even without strong exception, received. On the contrary, it is liable to considerable, though not, perhaps, overpowering objections. The sum of air consumed by the fires of London, for instance, in one year, has been computed at two hundred and thirty thousand millions of cubic feet †. Hence these obvious reflections may be made; that the daily consumption of air, in a populous city, must occasion an indraught of air, from all the adjacent parts, so as to form sensible currents of wind, which will be much increased by the perpendicular ascent of the rarefied and lighter air, which will be constantly going off in upper currents of a contrary

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* Fothergill. † Philosophy of the Elements.

trary direction to the lower air; and that all this may probably contribute more to keep such a place healthy, provided the passages are open enough to receive the benefit of the circulation, than all the noxious fumes that are raised there can do to infect the atmosphere, and render it unwholesome. I am aware, indeed, that the smoke of common fuel (not to say any thing of the breathing of animals and other phlogistic processes,) is, besides the water which rises first, an heterogeneous matter capable of ignition; in short, an inflammable air. I know, likewise, that coal yields near a third of its weight in air, and that near five hundred thousand tons of this air is calculated to be dispersed in the atmosphere over London, and that it is supposed to be a *fourth part* * of the whole quantity of air which is respired by the inhabitants of London in the course of a year. The levity of the mephitic air, and the constant rarefaction of the atmosphere of great towns, however, will always be the certain means of an incessant renovation of good air from the country, to replace that which shall have been exhausted. At the same time it must be acknowledged, that the pure air in the atmosphere of the country, exceeds that in the atmosphere of a populous city. Bergman,

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* Bishop Watson.

man, from experiment, declares, that the air of the country is two-thirds of fixed and phlogisticated airs, and one third of dephlogisticated air; but that the air in or near cities is much more contaminated.

But, the very accurate and ingenious observations of Doctor Ingenhouz shew, that it is not from the country, or even by residing in it, that the air most beneficial to human existence is to be found: for he declares, that the air at *sea* and close to it, is in general purer, and fitter for animal life, than the air on land, though it seems to be subject to greater diversity in its degree of purity than that of the land: and that probably, the air will be found in general much purer, far from the land than near the shore, the former being never subject to be mixed with land air. But, yet I should doubt, whether local situation, particularly low ground, might not be adverse to this doctrine in a general sense. By the heat of the sun, an *acid vapour*, we know, is exhaled from the sea; for such is positively proved, from the different states of the atmosphere in hot and cold climates.* For instance, in Hudson's Bay and Russia, metals hardly ever rust; whereas in warmer regions they always do, as well as in places abounding with salt springs. Be this, however, as it may, it is the variation in the pressure of the atmosphere, which in common affects animals, especially those of the human species. Thus in serene, clear weather, when the atmosphere is more heavy, we are generally more chearful and vigorous; the greater weight of the atmosphere bracing our fibres much better: but in foul and rainy weather, when the barometer is low, we are generally languid and dull; the air enclosed within the body being counterbalanced by a less external weight, distends the body, and occasions flatulencies, pains, and uneasiness. Besides this, the symptoms observed in our bodies in bad weather, may be in a great measure supposed to be owing to the *dampness* of the air at the time.* In the winter, when the weather is clear and frosty, the air has been generally found to be in the purest state; probably, because the corruption of so many substances is at that time retarded, and in a great measure hindered by the cold. In autumn, on the contrary, when a vast variety of vegetable and animal substances are hastened in dissolution and putrefaction by heat and moisture, the air is less pure.

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* Priestley.

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* Cavallo.

The rarefaction of the air has at all times a surprizing effect upon the animal constitution. At the height of six or eight thousand feet above the level of the sea, this effect becomes striking. The muscular force becomes exhausted; an universal faintness and lassitude prevails; the limbs, without frequent repose, refuse to perform their functions; the heart beats with an oppressive rapidity. This is all occasioned by the diminution of the compressive force of the air on the surface of the frame, whence the vessels suffer an unnatural dilatation. For instance, we may be supposed, ordinarily to bear a weight upon our bodies of 22033 pounds of air; but at the height of 7500 feet, this weight is diminished 5508 pounds, seven ounces, or exactly one quarter.* And hence the absolute necessity of having a fresh circulation of atmospheric air in apartments, which have had fires, lights, and company, each of which act powerfully in exhausting the heavy, and in augmenting the light air. Not that fires, in all instances, are to be considered as injurious, but the contrary; for although they may owe their energy to the good air which they destroy, they yet must be allowed to be agents well qualified for the purification of the atmosphere, for the acid they furnish combines with the putrid particles, and destroys their power. The Egyptians, it should seem, were very early acquainted with this efficacy of fires. The Greeks also were early enlightened on the subject. Acron, we are told, reaped the greatest honour, during the raging of a plague at Athens, by ordering fires to be kept up near each person that was affected. Hippocrates went further, and had fires lighted up in every street, and in every public place.*

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* De Saussure.

Bergman, in considering the situations most probably endowed with the purest atmospheres, says, "that from the gravity of fixed air, it follows, that the lower strata of the atmosphere must abound more with it than the higher; for the prodigious quantity which is generated by fermentation, putrefaction, effervescence, and other natural operations every day going on, for the most part remains close to the surface of the earth, and this must be again fixed by the continual generation of new bodies: and hence," concludes he, "the reason I imagine is plain, why *higher situations* are in general more healthful than lower ones."

The long life of man, we know, greatly depends upon the goodness of the air which he daily respires. The best aliments are not able

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* Plutarch.

to guard us against disease in bad air, or in an unwholesome country. The atmosphere that lies over the surface of the sea, as I have already said, is the purest; and this probably arises from the absorption of the mephitic particles by the mass of the waters. The air of the country is, in general, somewhat better than that of towns. Marshy grounds are, from their nature, unhealthy; and they are most so, when not cultivated. Good land even suffered to run waste, is injurious to man. Of this you have an instance in the *Campagna*, and in the environs of Rome. The insalubrity of the air, which is experienced in these parts, is in a great measure owing to the want of cultivation; and to the want of trees and vegetables, which would feed upon the bad, and return to the atmosphere a dephlogisticated air. This insalubrity, as you well know, is felt most in the summer, and in the night. During the day, the heat of the sun rarefies the air, and dissipates the mephitic exhalations. In the night, the septic or putrid exhalations, indeed, continue; but they hover round the dwellings of men, for there is no heat to raise and to disperse them. Even those which had risen during the day, fall again upon the earth. All hot countries, that are low and damp, and not well cultivated, are always unwholesome. Dry, rocky, sandy countries, even without vegetation, are quite the contrary. If near the sea, so much the better. Hence the healthiness of the situation of Gibraltar.*

But, here it may be asked, how these airs are concentrated, held, and ultimately set loose? The generation of airs is owing to the concentration of fire; for the airs are produced in that regular order, which is conformable to the quantity of fire they possess. For instance, let us take the air from lime-stone. First, fixed air is expelled without any impregnation; next, phlogisticated air, with sufficient to neutralize the acid; then dephlogisticated air, with an higher impregnation; and at last inflammable air, which always varies with its substance, with the highest concentration. Vegetable bodies, indeed, as we have seen, are principally formed of the vegetable acid, with water and an earthy base, and these attract the fire of the sun, and concentrate it. When these again are exposed to the fire, the fire is attracted and concentrated likewise, and forms charcoal; and when the heat is pushed high, the concentration is so considerable, as to form inflammable air;

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* Ingenhouz.

but if an over proportion of water enters, a proportionally less quantity of fire enters, and thus fixed air is formed. Hence it is also, that phlogiston and the nitrous acid form nitrous air; but, by adding a greater proportion of phlogiston to the air already generated, or before its generation, it will produce either inflammable or empyreal nitrous air. The same happens with regard to the vitriolic acid air. In the marine acid air, it is the same: by exposing it to iron, it will reduce the iron into a calx, seizing upon its phlogiston, and forming inflammable air. Every chymical process is a proof, that fire is chymically united with acids. When exposed to a strong heat, they become aerialized into phlogisticated, empyreal, or fixed airs.*

Swamps, morasses, and undrained and uncultivated lands, let me again repeat it, are fatal to the health and longevity of man. They send forth the seeds of pestilence and death upon the wings of every wind. They are the most certain, and the most durable calamity, that ever afflicted the human race. In every gale, the whole mass is tainted with putrescency, and teems with variety of life. The living atmosphere,

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* Dr. Harrington.

mosphere, instead of the *pabulum vitæ*, becomes the indiscriminate dispenser of pain, sickness, and animal dissolution. In short, every thing becomes pestiferous. Of the effect in a smaller degree of corrupted air, a familiar instance occurs in *cretins* and *goitres*, which are chiefly found in those countries where there is a rank vegetation, and where the atmosphere is extremely humid, in consequence of numerous lakes, water-falls, and rivulets, which emit powerful exhalations through the influence of the sun's heat, while they are excluded from every drying wind. They, for example, who inhabit the deepest and most recluse vallies, are reduced to the lowest state of imbecility and idiotism. In those which are somewhat more elevated, the mental powers are not so completely obtunded; and others still more elevated, and exposed to fewer exhalations, and more salutary winds, will merely be deformed with wens and swellings about the joints. They who are nearer to the summits, are perfectly exempt from all these appearances. The inhabitants of more healthy vales may, indeed, become cretins, by residing in such unhealthy regions; but, it is at the same time more than conjectural, that the race of cretins may be meliorated, by transplanting them to a more salubrious soil. All this you may observe among the Alps, or, as it more powerfully struck me, among the mountains of Stiria, Cerinthia, and Carniola. And if you still go further, you will find that direful scourge, the plague, propagated or destroyed by similar causes. At Constantinople, it prevails during the summer, and is greatly weakened, or entirely ceases, in the winter. In Egypt, on the contrary, it is most violent in winter, and infallibly ends in the month of June. This apparent contrariety, however, is to be explained on the same principle. The winter destroys the plague at Constantinople, because the cold there is very severe; and the summer revives it, because the heat is very humid, on account of the seas, forests, and adjoining mountains. In Egypt, the winter nourishes the plague, because it is mild and humid; but the summer destroys it, because it is hot and dry. It seems to act on it, as it does on the flesh of animals, which it does not suffer to corrupt.*

I would not willingly drop a word here, which in any respect might be liable to the construction of prejudice, or national partiality; but, I feel too strongly the impulse of truth, to withhold the remark, that it is a practice not

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* Volney.

always rational, though common among us, to send our invalids annually to Italy, or to the southern parts of France. Is the deadening sirrocco wind, which is immediately succeeded by a *tramontana*, the *bise*, or, in short, the variable extremes of hot and cold air, which one is exposed to in the neighbourhood of the Alps and Apennines, the salubrious stream by which a sick man should be surrounded? Sudden atmospherical transitions are most pernicious to human nature. In every climate, they are injurious to the frame. In England, indeed, which is temperate, their influence is generally exerted on the relaxed and weak. But in England, who does not feel the easterly wind? "At Lausanne," says Dr. Moseley, "Tissot told me, the transitions from heat to cold are there sometimes so great, that invalids and convalescents feel considerable ill effects from them; and that in pulmonic disorders, those changes have produced the most dangerous consequences. Why then expatriate one sick person? Why separate him from his friends, and hurry him into a climate more fickle, and consequently more unwholesome than his own? Towns, within the reach of winds from the Alps, Apennines, Pyrenees, and other high mountains, at some seasons of the year, are graves to people who resort

sort to them, in decays of the lungs. In these scrophulous and consumptive habits, to which our atmosphere is inimical, sea voyages should be made, and islands should be resorted to, where the climate is uniformly warm; such as Madeira: or others still in warmer latitudes, which have been known to succeed better. Few diseases originate in England, for which the climate of England, with change of place, is not equal to any other. Foreigners have an erroneous notion of our climate. Perhaps our atmosphere is not mild enough for the tender fibres of weak bodies; but, take it for all and all, there is not a better climate on the habitable globe. For by what fairer comparison is a climate to be estimated, than by the corporeal and mental faculties of those who are nurtured in it; and in which almost every species of animal arrives to the utmost perfection? *

But, I now will take my leave, and sum up our aerial dissertation in the words of a celebrated physician.† "It is supposed, and I believe justly, that more of the offensive particles are swept off by the air which has been received into the lungs, than from the whole surface of the body besides: and this is the reason, why the

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* Dr. Moseley. † Adair.

air we breathe is so soon contaminated, and rendered unfit for the support of life; and this in proportion to the air being less pure, previously to its being inspired; because thus tainted, it is sooner saturated with the noxious matter it takes up in the air cells of the lungs, and therefore carries off a smaller proportion in a given time: whereas, a purer air would unite with, suspend, and discharge a larger quantity, and thereby prevent the dangerous effects of their retention. Hence it is, that a moderately cold and dry air is the most wholesome: for the lungs, like the funnel of a stove, discharge the foul air, by means of the cool air admitted by every inspiration.

LETTER XXII.

FROM fire and air we now naturally turn to the element of water. Water, in general, implies a pellucid fluid, convertible into ice by cold at 32 degrees of Farenheit's thermometer, naturally pervading the strata of the earth, and flowing or stagnating on its surface. It is usually divided into two general kinds, the simple and medicinal. Simple or pure water, in the strictest sense of the word, is not met with any where. Heterogeneous matter, and that in a large quantity, may be separated from such as appears the purest and most simple. But we include, in a more general manner, under the first of these terms, all those waters which have no smell or taste of any extraneous matter, nor any particular effect on the body; and under the latter we include all those whose smell, taste, or other obvious qualities, denote their containing saline, metalline, or other mineral particles in them, and whose effects on the body correspond with these notices of their contents. In a word, we may look upon that water as most pure, which is limpid, without colour or smell, breaks soap readily, boils pulse soon and tender, which freezes readily, and does not encrust the bottom or sides of vessels in which it is boiled. And hence the water which is raised in vapour, and as it were distilled by nature, is of the purer kind; whilst that from ice is the purest of any, as the grosser mineral and heterogeneous particles which all waters contain in a greater or less degree, are probably excluded. The sailors to the Greenland Whale Fishery, who for many months have no other than ice water to drink, have always found it so. Our intrepid and celebrated countryman, Captain Cooke, brought this to an indisputable certainty.

In the sublime arrangement of the elementary principles of nature, the Almighty Ruler of the whole, we may with humility conclude, did not, in the separation of the respective masses, render the two oceans of water and air, so wholly discordant from each other, as that they should be incapable of contracting an union! On the contrary, they have such a disposition to unite, that it has long seemed to ingenious men, that they have had a common origin, and that if it were not for the intervention of heat, they would probably unite, and again compose a common masss.* The water on the surface of the earth is constantly replete with air, and the atmosphere is replete with water. The numerous tribes of aquatic animals, which inhabit the ocean of waters, would perish if it contained no air; and it is no improbable conjecture, that the animals which exist in the ocean of air, would perish if it contained no water.

As we have already observed, water has, through all ages, been considered as an element, because it was always deemed impossible to decompose it, and because it was to be extracted from almost every substance in nature. Found under three forms, ice, fluidity, and vapour, it seemed one of the great agents of this terrestrial world. It served to form mountains, to kindle volcanos, to dissolve saline substances, to purify and to load the air, and to crystallize particles of earths and minerals, so as to render them solid and considerable bodies. *Ice*, however, was looked upon as its primitive state; for the first state of a body, at least chymically considered, is that in which it is in the greatest possible aggregation. Thus ice must be the aqueous element, not water, which is a compound. Of this original state of water, these few circumstances, out of a great many, may be considered. In forming into ice, water gives a heat, because it is a fluid becoming solid. Air favours the production of ice, for water, hermetically sealed, will freeze but slowly. Ice swells to a larger size than the bulk of the water before its congelation, though it has less weight than the water, upon which it can float. Its elasticity is greater than that of water, and its savour is much more pungent. And, lastly, it has a strong propensity to combine with light, with air, and with salts. *

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* Bishop Watson.

But water in its fluid state, in which we are for the present to investigate it, was always known to be upheld, not only in the earth, but in the atmosphere, by particles of fire. In its general mass of the ocean, it was never found freed from phlogiston. As an aerial substance, however, it was generally believed to have had a strong attraction to various matters, such as marble, glass, &c; and that from this attraction proceeded the moisture which was frequently observed to be generated upon those substances. This was, however, attempting to explain scientifically what was not certainly understood; and I merely mention it to shew, that though so long

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* Fourcroy.

long ago as Aristotle, this phænomenon was ingeniously accounted for, it yet was supposed to require something more for the conviction of the experimentalist. Aristotle, speaking of it, says, "Elements which have one common origin easily change from one to another; you have only to destroy the principle, which causes the separation." For instance, let a foreign body dispossess water of its coldness, and communicate to it heat, it immediately assumes the characteristic of air. On the contrary, as in elevated regions, let this air be deprived of its heat, the particles return to their original coldness; they assume their original form, and in such shape fall upon the earth in rain.

The moisture, therefore, thus observable upon certain substances, so far from being attracted, was rather stopped by them. They offered a free passage to the fire, while they refused admittance to the water rarefied by it. Thus, when there is more fire in the air contained in a room, than in the wall, the fire endeavours to expand itself equally, and therefore cannot penetrate into the narrow pores of the marble, without leaving thousands of particles of water at the entrance of these passages. And hence the reason why a glass, having cold water poured into it, appears cloudy. The water contains less fire than the external air. The fire from the air, then, expanding itself through the pores of the glass, leaves the water hitherto supported by the action of the fire, which is refused admittance, and consequently appears in drops upon the surface. Pour out the cold liquor, and a moist cloud will appear on the inside of the glass, as it did before on the outside, because all or the greater part of the fire, lodged in the substance of the glass, being dispersed in the cold liquor, that liquor is no sooner poured off, than the fire contained in the air penetrates both sides of the glass at the same time. Yet, when the aeiral fire has once regained its equilibrium, the former appearances will cease. *

From this mechanism, and the natural effects of the fluidity of fire, many important questions, it was conjectured, might be resolved. During our late researches, however, we had occasion to look somewhat closely into the two most dissimilar permanently elastic fluids we are acquainted with, the phlogisticated and dephlogisticated airs. Philosophers, in experiments upon these fluids, conceived that they would unite; inflammable air having been found to change

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* Spect. de la Nat.

change into vital air. Hence they contended, that they formed an aerial acid, or when in a large proportion, a corrupted air; by which change a great quantity of specific heat was necessarily let loose, and being accumulated, produced ignition, and even flame, when inflammable air was present.* Scheele contended that vital air might be totally changed by phlogiston into the *matter of heat*. Both opinions were supported by strong arguments, and Kirwan was of the first. But as Bergman's very able translator says, "I must confess myself ignorant of any good reason for believing phlogisticated, foul, or corrupted air, to be a modification of vital air." Notwithstanding which, the opinion was pretty generally adopted, and it was believed that fixed air was generated in phlogistic processes, by the union of vital air with phlogiston.

But during this examination of the union of these airs, it was little imagined they would be declared to be constituent parts of the body of water. Cavendish was the first with us, who promulgated this extraordinary fact. He imagined he found, that passing the electric spark through phlogisticated and vital airs, he reduced them positively to water. In his trials, a diminution of bulk was at first observed, insomuch that where five parts of vital air were added to three of common air, almost the whole disappeared: but, when phlogisticated was substituted for common air, the whole product then appeared as water; more than forty-nine parts in fifty. Thus was he enabled, as he conceived, to shew that vital air was the same thing as water deprived of phlogiston: and that the union of phlogisticated and dephlogisticated air formed the element of water.

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* Bergman.

This condensation of airs into water, by Cavendish, soon drew the attention of the ingenious of all nations. It was every where tried, and I believe every where generally subscribed to, excepting by the celebrated Mons. Achard, who thought the phænomenon which had been employed to prove that water is a combination of dephlogisticated and inflammable air, proves rather that air *results* from the *combination* of *water* with the *igneous fluid.* Wherefore, according to him, the decomposition of air must produce water, and consequently the experiments, on which Cavendish and Lavoisier's theory of the composition of water is founded, cannot be considered as a proof that water is composed of the two kinds of air, from whose *combustion* it is obtained; as the water obtained is not the production, but merely one of the constituent parts of the mixed air, which has undergone combustion. It has likewise been said, that a doctrine, giving to the oxigene and hydrogene gases, two of the most combustible bodies in nature, the property of forming water, is little less than philosophical extravagancy: the same materials, are moreover given to the formation of the nitrous acid. Why, it is asked, may not water be considered in fact, as Boyle considered it, as an aerial earth, possessing a considerable quantity of latent fire? Ice, by having a greater quantity of heat thrown into it, passes into water; and why may not earth, by having a greater quantity of heat thrown into it, pass into water also? Moreover, although it is the present fashion, not to consider water as one of the kingdoms of nature, why has it a better right to be distinguished from a solid, elastic, diaphanous substance, than a melted metal hath to be distinguished from the same metal, when concreted into a solid form? In their different states of fluidity and solidity they will have different properties; but, should they, from such accidental changes as are effected by minute variations of heat, be referred to different classes?

Had water been called melted ice, who would have scrupled to consider it as belonging to the mineral kingdom? The reducing quicksilver into a solid, malleable metal, by a degree of cold, was an important discovery in physics. We learn, thence, to consider all fluid bodies, such as water, oils, spirits, æther, and probably the air itself, as convertible into solids, without the introduction of any frigorific particles, but simply by a diminution of heat; and all solid bodies as convertible into fluids, without suffering any other change in their constitution, except what arises from the volatilization of such of their principles as cannot sustain the degree of heat requisite to render the rest fluid.*

To all this, however, it is said, that accurate experiments have compelled chymists to deprive water of its dignity as an elementary principle, and to class it among compound substances; for that all the phænomena of nature and of art conspire to prove the same truth. At the same time it is allowed, that water may be considered as the general cement of nature. Existing in a state of combination in bodies, it concurs in imparting to them hardness and transparency. It exists in this form in crystals, &c. which immediately lose their transparency on being deprived of their water of crystallization, or their generative water, as it has been emphatically styled. Some bodies are indebted to it for their fixity. The acids, for example, acquire fixity only by combining with water. In a word, it is agreed upon all hands, that water, when disengaged from its combination, and in a state of absolute liberty, is one of the most considerable agents in the operations of this globe. It bears a part in the formations and decomposition of all the bodies of the mineral kingdom; it is necessary to vegetation, and to the free exercise of most of the functions of animal bodies; and it hastens and facilitates the destruction of these bodies, as soon as they are deprived of the principle of life. And thus, all philosophers, until these very few years, in a similar spirit to that of Thales, looked upon water as the elemental matter, or stamen of all things. Even Newton says, "all birds, "beasts and fishes, insects, trees and vegetables, "with their several parts, do grow out of water, "and watery tinctures and salts; and by putre"factions, return again to watery substances."

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* Bishop Watson.

On whichsoever of these grounds, however, this subject comes to be considered, the close affinity of the elements will be demonstratively proved; together with the chymical position, that bodies never blend, excepting their natures be different, or they be united by the intervention of a third substance. As for instance, oil and water will not mix, and yet when the oil is combined with a salt, there results a soap which is soluble in water. Bodies of the same nature, only increase the bulk of the same matter. And hence it is, that acid salts opposed to alkalis, so intimately combine; that we find the same opposition between alkalis and sulphur; salts and oil; acids and metals; spirit of wine and water; all of which have a great tendency to unite, and to form a most intimate combination.*

From considering water in its constituent parts, let us proceed to contemplate it in the aggregate. *Fluid* in physiology, is an appellation given to all bodies, whose particles easily yield to the least partial pressure, or force impressed. Some philosophers, however, make the following distinctions in fluids: those which flow or spread themselves till their surfaces become level or horizontal, they call *liquid*, in contradiction to flame, smoak and vapour, which are also fluids, but do not acquire such a surface: those which are capable of exciting in us the idea of moistness, as water, they call *humid:* distinguishing them thereby from air, quicksilver and melted metals. But these distinctions are unnecessary; the surfaces of all fluids being level or horizontal, when not prevented by the bodies about them; and humidity is only a relative quality; for though quicksilver will not moisten, or stick to your finger, it will to silver or gold.

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* Fourcroy.

The nature of a fluid, as distinguished from that of a solid or hard body, consists in this, that its parts are so loosely connected together, that they readily move out of their places, when pressed with the least force, one way more than another. Whence philosophers conclude, that these particles are exceedingly minute, smooth, and round; it being otherwise impossible they should move with such freedom, upon the least inequality of pressure. All particles, considered separately, are supposed to be endued with all the common properties of matter, and are subject to the same laws of motion and gravitation with larger bodies. And, indeed, the shapes of other bodies seem clearly to corroborate the globular figure of fluids; for the figure of a substance, it is to be supposed, naturally arises from the figure of its parts.* The small grains of sea salt and of lead are cubical; nitre is hexangular; blood and oil are globular; corrosive sublimate spiculated; and antimony is in small filaments, like needles. Hence the effects of bodies may be conceived to follow from the configuration of their particles: as for example, the spiculated are sharp and corrosive; while the globular are insipid and balsamic. Spicular poisons, antimony and sublimate, may be rendered inoffensive by sheathing their points in oil or in wax.

Liquids in general, says Bergman, must be considered as solid molecules, too subtile to be perceived by the sight, however assisted; and on account of their levity, bulk, figure, or by the interposition of another fluid, moveable with the greatest ease, and affecting an horizontal position. Hence, since sand in a very attenuated and volatile state preserves a level, so that animals may be drowned in it; since pounded gypsum set in a vessel over the fire, seems liquid; why should not water be supposed an earth kept liquid by heat? it certainly concretes into a solid body, when the heat is diminished to a determinate degree; but, when the heat is increased to a certain point, it is resolved into elastic vapour.

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* Philosophy of the Elements.

Fluids exert a force of pressure equal to their gravity every way, or in all directions equally: thus there is an equilibrium, or state of rest throughout a fluid; it being an axiom in philosophy, that a body urged in every direction equally, will be as perfectly at rest, as if it were affected by no force at all. Action and re-action are ever equal between any two bodies, and in contrary directions: for instance, if you press a stone with your finger, your finger is equally pressed by the stone; or if an oar strikes the water in one direction, the water re-acts, and moves it in the other direction. From the gravity of fluids arise their pressure, which is always proportioned to their gravity; and since we may suppose all the particles of a fluid to have equal bulk and weight, the gravity of the fluid, and consequently the pressure, will be always proportional to the altitude or depth. But the supposed incompressibility of liquids, was for a long while looked upon as one of their most striking characters; for it was imagined they could not by any force be compressed into a less space than that which they naturally possessed; and this was thought to be accurately proved by the Florentine experiment, of filling a globe of gold with water, which, when pressed with great force, causes the water to transude, or issue through the pores of the gold, in form of a dew all over its surface. This phænomenon, however, did not prevent M. Canton from proving, by undeniable experiments, the compressibility of fluids, and that the contrary conclusions were erroneous.

But, notwithstanding the general opinion, that the particles of fluids are spherical, and in consequence of their touching each other in few points, cohere very slightly, and easily slip or slide over each other; it has been conjectured by some,* that the particles of fluids are of the same nature or figure with those of solids, and that from the very ready *conversion* of the one into the other. The original cause, therefore, of fluidity, say the supporters of this opinion, does not appear to consist in the figure of the particles, but, simply in their want of cohesion. This, however, is not for our present discussion. As the unknown principle of mutual attraction between the constituent parts of solid bodies, is the cause of their solidity; so the unknown principle of fire, is the cause of their fluidity.* I call the principle of fire, notwithstanding all we have said about it, unknown, because, though its effects are sufficiently manifest, the cause of it is undoubtedly questionable. It is the great instrument of fluidity. Without a certain degree of it, water, spirits of wine, oil, quicksilver, and perhaps the air itself, would be converted into solid bodies; and with a certain degree of it, all fluid bodies would be changed into elastic vapours; and all solid bodies would either be wholly dissipated, or in part dissipated, and in part converted into fluid glass.

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* Cavallo.

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* Bishop Watson.

LETTER XXIII.

WHATEVER may be the cause, or however occult the doctrine may appear, it is yet most evident in the eye of experiment and investigation, that all bodies in nature have a reciprocal attraction: they search, as it were, and make efforts to approach, one another: this is the grand law on which depend all the phænomena of the universe. This force is essential to the harmony of the world. It reigns in the smallest bodies as powerfully as in the largest. In two drops of the same fluid, whether water, mercury, or oil, it is peculiarly striking. Put them at a certain distance, and on a plain surface, you will perceive them moving towards each other, and at last uniting, and making one single globule. This latter, indeed, is said to be different from attraction. It is called combination. Attraction is held to exist between bodies at certain distances. Combination, only when the molecules touch each other. But, in fact, it is as difficult to discover the cause of chymical affinities, as to discover the cause of attraction or magnetism.* It has been shewn by Newton, says Bergman, that the great bodies of the universe exert the power of attraction, directly as their masses, and inversely as the squares of their distances. But, the tendency to union, which is observed in all neighbouring bodies on the surface of the earth (and which may be called *contiguous attraction*, since it only affects small particles, and scarcely reaches beyond contact, whereas remote attraction extends to the great masses of matter in the immensity of space) seems to be regulated by very different laws; it *seems*, I say, for the whole difference may perhaps depend on circumstances. The figure and position of the particles, we are by no means able to ascertain.

We are now to observe attraction in its most beautiful, as well as in its most sublime appearance. The immense body of waters with which the greatest part of the globe is covered, boldly exhibits it in its fullest energy. The sea shall first engage our attention. Many and most contradictory opinions have been held, relative to the waters of the ocean. But, the bason in which they are contained, is of such immense extent, and covered, in many places, with such an unfathomable depth of water, that it is impossible it can be traced in every part. It yet in some measure may be guessed at. One thing, at least, seems certain, that at the bottom of the sea there are considerable mountains, and other irregularities. It is perhaps as irregular as the surface of the land. With regard to the qualities of its soil, little can be said. It must, however, be composed of the same materials as the surface of the earth. The same substances are found in both; shells, madrepores, corals, marbles, &c. And to these irregularities, we must ascribe the origin of many of our currents:* for a current is a river, the breadth of which is determined by that of a valley through which it runs; its rapidity is proportioned to the force by which it is produced; and its direction is marked out by the position of the irregularities.

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* Fourcroy.

But, in what manner are we to contemplate this tremendous excavation of our globe? We cannot look upon it as a chasm, scooped out like the bed of a stream which is precipitated from the mountains! If we could imagine the channel of the sea to have been made, as we may imagine the channel of rivers, by long and insensible attrition, the water wearing by degrees the ground under it, by the force derived from its descent and course, we should not wonder at its form; but it is impossible that this channel should have had any such original.* Whence should its waters have descended? from what mountains, or from what clouds? where is the spring-head of the sea? what force could eat away *half the surface* of the globe, and wear it to an immeasurable depth? this cannot have been from attrition. But, God so ordered it, when he separated the waters from the dry land.

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* Buffon.

Water, from the earliest ages, was a symbol of the Divinity. It was part of the ancient Cosmogony, which looked up to the Divinity as to the Lord and Ruler of those waters, which was conceived to have been employed in extinguishing the ever-consuming fires of the world. Hence the *Hindoos* also believed, and invariably have continued of opinion, that their most sacred river, the Ganges, issues immediately from the feet of Brouma. And hence, likewise, the reverence which the ancients had for rivers, fountains and springs, and which led them to the allegorical conclusion, of their being watched over and guarded by tutelary divinities.

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* Burnet.

Of the most striking characteristics of the waters of the ocean, one is their saltness; together with their being more buoyant than fresh water, and approaching consequently nearer to a solid, from the various heterogeneous particles with which they are saturated. On this subject, Buffon observes, that all lakes that give rise to rivers, and all those which occur in the course of rivers, are *not* salt; but that almost all those, on the contrary, which receive rivers, but give rise to none, *are* salt. This circumstance, says he, seems to favour the opinion, that the saltness of the sea is occasioned by salts brought down from the land by the rivers; for we find that salt does not evaporate. All remains in the sea: it, consequently, is always augmenting.

But this conjecture, that the water of the sea was *fresh* at the beginning of the world, however sanctioned by other names of celebrity as well as by that of the illustrious Buffon, seems extravagant and unsatisfactory. The saltness of the sea, we must in common sense suppose to be as necessary to the constitution of that element, and to the well-being of the terraqueous globe, as the redness of the blood is to the animal system. The sea can be no more salt by chance, than the blood is red by chance.* As it occupies a very considerable proportion of the globe, providence assuredly endued it with properties essential and peculiar to itself. Not but that the water of rivers generally contains a small quantity of salt. The saltness of the sea, however, which arises from one fortieth part being salt, and from its being nearly of an equal saltness at the surface and at the bottom, must have been coeval with its original formation.

The waters of the ocean, besides salt, are impregnated, as I have already said, with heterogeneous particles, and particularly with calcareous marine salt, and not as has been supposed, with bitumens, which in reality have no existtence: nay, as vitriolic water will in the course of time render cast iron so soft, that it can be cut with a knife as easily as black lead, so sea water, acting on iron guns, has been found to have the same effect: it has made them as soft as tin, though in 24 hours, by being exposed to the air, they have recovered their original hardness.[*] Notwithstanding this, the salt water of the sea is observed to freeze into fresh water, that is, into ice, which, when dissolved, appears to have lost its saltness. Water, with that degree of coldness which is necessary to freezing, cannot retain the saline and other particles suspended in it.

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* Philosophy of the Elements.

As the pillars and foundations of the present exterior earth, therefore, stand immersed in water, at a certain depth every where from the surface water is always to be found, provided the soil be of a nature to admit of it.[†] It is true, all subterraneous waters do not proceed from this original, for many of them are the effects of rain and melted snows. But, digging any where, you constantly come to water, even in the most solid grounds; and this cannot proceed from rains or snow, but must come from below, and from a cause as general as the effect. The fact is, the water is as ancient as the earth, and contemporary with it. It almost always holds in dissolution, saline, earthy, sulphurous, or metallic substances. The selenite in fresh water, is that which is the most frequent; and that more particularly in wells than in rivers; and hence it is that well-water is not proper for dressing vegetables, for it in some degree, closes their pores with the selenite, and prevents the water from penetrating: hence too it is, that let a shrub be for a certain time watered with a strongly impregnated selenitous water, the roots will be found encrusted with a gypsum, and the tree will perish. For other domestic purposes, also, well water is in general, found less useful than rain or running water; for instance, in the laundry, for it decomposes the soap.

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[*] Bishop Watson. [†] Burnet.

LETTER XXIV.

DURING the revolution of ages, mankind had been inattentive to the phænomena of lakes, springs, and rivers. These objects at length, however, came to be considered; and the science of physics began to dispel the clouds of ignorance. But, yet it remained, as it must be confessed it at this moment remains, in doubt, whether our most generally received opinions on the subject, be not in some respects chimerical. We will endeavour, however, to investigate them, and whatever the result may be, it shall at least legitimately grow out of the premises which we shall establish.

The mean depth of the ocean has been computed to be 230 fathoms. But, why so inconsiderable a depth? of an unmeasured fluid, we can only reason by conjecture. The summit of Mont Blanc is more than ten times that elevation, and yet that summit bears marks of a close and intimate connection with the waters. The profundity of the great deep, therefore, is not to be ascertained. It may be miles;—it may be leagues, for even imagination cannot trace its limits: the elevation, and the inequality of mountains from the surface of the earth, can alone be conjecturally admitted as standards of its unascertained depth. It has, however, been maintained by philosophers, that from the prodigious mass of the ocean are derived all the lakes and rivers of the world; and Halley is said to have demonstrated, that evaporation is the immediate cause of their existence. Halley's hypothesis, which was received by the learned world with universal applause, may be understood by the two following propositions: 1st. That the vapours which arise from the sea, are much more than sufficient to supply both the surface of the earth and the rivers, with waters. 2d. That the mountains do, by their particular structure and formation, attract, and as it were arrest, the vapours and the rain that float in the atmosphere, and having collected them in their reservoirs, dismiss them again through their sides, either in perpetual or intermitting currents. By Halley's calculations, as an example, it is likewise said, there is little more than one third of the quantity of water *received* daily into the Mediterranean, that is *evaporated* from it: and what would seem to prove this doctrine true, is, that rivers and springs are always found to run towards the sea, and never from it.

Rivers, undoubtedly, are only waters descending by their gravity from higher to lower parts of the surface of the earth, in proper channels; which are filled by waters collected on the tops of mountains, from rain, snow, fogs, dews, and even clouds themselves, and which run through various fissures into their internal cavities. The superfluous parts flow from those cisterns through different crevices to the sides of mountains, where they appear as bubbling springs, and stand in hollow places in forms of pools, ponds and lakes. Rivers, in short, are streams of water, which by their own specific weight move down inclined plains; six feet in a league being sufficient descent for their running. This is very nearly the descent of the Rhone from Le Pont St. Esprit to the sea.* And every where, where rivers are navigable, we may be assured the declivity does not exceed twelve feet a league. The Rhone has not so much from Lyons to Le Pont St. Esprit, although its rapidity, as you well know, is great the whole way.

The sea has no communication, says L'Abbé Pluche (as was formerly, indeed, the opinion of

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* De Luc.

Descartes and others) with the mountains, by any passage underneath the earth, but all *above* it. From the surface of rivers, from lakes and from the sea, a vapour incessantly arises, which is carried through the regions of the air, by the impulse or action of the wind, in the form of a cloud or mist; and which, in proportion as it meets with cold air, or its progress is obstructed by mountains, condenses, and descends in dew, snow, hail or rain. The quantity of vapour thus diffused upon the earth in water, is greater than all the rivers, taken together, disgorge into the sea. In England, for instance, from 40 to 43 inches of water in depth, is supposed to fall in the space of a year.

But all this doctrine, as I said before, is doubtful. It is uncertain, whether evaporation from the sea be sufficient to supply all the running waters; especially as the greatest part of that very evaporation falls again into the sea. Moreover it is conjectured, that a greater quantity of water is evaporated from continents than absolutely returns to them in rain; to which may be added the expence of that element, caused by animals, by vegetables, and by its consolidation into substances, concerning the nature of which, we shall in the sequel have occasion to inquire. From such circumstances, then, one would naturally be led to suppose, that there are other waters in the system of this vast body the earth, than those established upon the hypothesis, however able and ingenious, of Dr. Halley; and that there may be an *internal* as well as an external evaporation. The matter of electricity, and the matter of fire, are powerful agents. They are not of partial and circumscribed situation. They pervade, and most probably act upon nature, in her deepest recesses.

All the theories, however, of the phænomena of springs and rivers, may be reduced to two. Some say the cause is above the earth; others, below it: the former maintaining, that the rains which fall upon the earth are sufficient; the latter, that they are chiefly derived from the vapours, veins, and issues of the great abyss, into which they are all returned, and that a perpetual circulation and equality is kept up.*

To the first may be answered, that rain and vapour cannot account for the origin of all springs and rivers, because the rivers of a country have been compared with the rains that annually fall upon it, and have been found to *exceed* the rain in quantity. In Italy, for instance,

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* Philosophy of the Elements.

stance, it has been accurately calculated, that the waters discharged into the sea by the rivers of that country, are to the rains which fall upon the land, as 55 to 27, that is, more than double. And in Paris, the following calculation was made, from experiments, in three succeeding years.

Total de la Pluye 11 pouces, 6 lignes ½—en 1688.
Total de l'Evaporation 22 pouces, 5 lignes.
Total de la Pluye 18 Pouces, 1 ligne—en 1689.
Total de l'Evaporation 32 pouces, 10 lignes ½.
Total de la Pluye 21 pouces ½ ligne—en 1690.
Total de l'Evaporation 30 pouces, 11 lignes.

Sidleau.

Secondly, because the consumption of moisture by vegetables is so great, that all the rain that falls, is not sufficient to supply them with what their growth demands. For Dr. Hales found, that a plant in twenty one days and a quarter, drew off all the water of the earth on which it grew; so that without a farther supply from beneath, it must have perished after that time: and yet he made no allowance for what the portion of the earth in question perspired at the same time, by its own pores in vapour. Thirdly, because there are springs,

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and those every where common, so equal and constant in yielding their waters at all seasons, without being affected either by rains or droughts, that we cannot suppose them to depend on any such causes. Fourthly, because there are springs too near the summit of the highest grounds in the country, to be derived by descent from the water which falls on the surface of the earth; there being no declivity sufficient to account for them that way. As we have already said, however, it would be absurd to deny, that rain and melted snows produce springs, and increase the discharge of rivers, because we see the phænomena with our eyes; but this is a partial consideration, and by no means adequate. Let us try whether the question can be solved by means of the subterraneous stores, and the vapours that unquestionably arise from them.

If we penetrate deep enough, we never fail to find water; and the deeper we go, the water occurs in greater plenty. This does not look as if the lower stores depended upon any accident at the surface; for then they would rather be diminished, and fail as we descended, their supplies being extended in springs and rivers on the surface; but the contrary is always the case;

therefore, the sources are not altogether above, but some are below. When the earth is cut through, it yields water as naturally as the body, which abounds with vessels, yields blood when it is wounded. The deeper the wound the greater is the effusion of blood, because the larger channels lie deep; and the largest of all, which feed the rest, are placed in the central parts of the body.

Hales, indeed, objected to all supplies from an interior stock, because the surface of the sea, even at high water, is lower than the surface of the land.* But, in answer to this objection, we are to remember, that the waters of the sea are salt, while the spring waters of the land are fresh, and consequently higher; so that a column of sea water will be a counterpoise to an higher column of fresh water. If, therefore, the water of deep seas has any communication with the land, and it has its due effect, water may rise to any height required, upon the common principles of statics, either by running channels, or by sap or percolation; in which case, the effect will be forwarded by attraction; for a mass of dry sand with water underneath, will be soaked upwards to its surface. Sir Isaac

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* Philosophy of the Elements.

Newton tried this experiment, in a tube filled with dry ashes, and found that the water ascended through them with ease. In the rocky caverns of mountains also, much may be done by the slow ascent of *steam*, which will be condensed, as it approaches the air, and distil downwards, through those cracks and chasms where it finds an outlet.

From all this, it scarcely can be denied, I think, that the earth is full of open veins and fissures; together with strata of loose and permeable matter, and therefore, that it must have communication with the sea to very great distances. Steam and vapours are stirring at all times in the internal parts of the earth. At the greatest depths, there are sensible tokens of moisture, rising upwards from the lower parts. But the convincing experiments of M. de la Hire, who found that the rain of fifteen years conveyed not one drop of water to the depth of eight feet, through loose and permeable earth, that was properly exposed to it, and had a drain made at the bottom to discharge the water, if any had been collected, sufficiently demonstrates, that the origin of *all* springs and rivers is not from above.

Water, we know, ascends in vapour to a prodigious height in the atmosphere. Why may it not therefore ascend in the same manner in the bowels of the earth, and thereby form springs, and ultimately rivers? Fire, and the electric fluid, abounds in the earth, and by these we have reason to suppose, that the aqueous particles are held in suspension. Now steam, if it be gradually cooled to 212 degrees, though the cooling cause continues to act, the temperature becomes stationary, till the steam, by parting with a portion of its specific heat, is all condensed into water: this water then cools, though less gradually than the steam did, till it arrives at the temperature of 32 degrees: it then again becomes stationary, till, by parting with another portion of its specific heat, the whole of the water is converted into ice. Thus steam consists of particles in an elastic state, or disengaged from their mutual attractions; water consists of the same particles, exercising their attractive power on each other, and thereby cohering together; and ice consists of the same particles, still more strongly cohering, or crystallized into clusters or masses.

This then being the process, in some respects internally, as well as externally, is it not rather extraordinary, that men shall at the same moment assert, that there is water enough in the atmosphere, held there by fire, to deluge the globe, and deny the possibility of springs being generated in the interior parts of the earth by the same agency, the same interior parts of the earth being the very pabulum of fire? The proof, however, that springs gush from channels, similar to veins in the human frame, is, that hundreds of miles from mountains, and in the midst of the ocean, a little sandy island, scarcely more elevated than to be horizontal with the surrounding fluid, shall afford springs of fresh water. From what level, upon any principle of hydraulics, can these waters be supposed to be deduced? For my own part, I cannot conceive. But Philosophers guess, when they cannot demonstrate; and hence, on this subject, they are generally found to be positive in the fancy, for it in fact is no better, that the cause of lakes, of rivers and springs, is from above, and fortuitous.

The origin of springs, you thus perceive, has been greatly controverted among naturalists. There are, however, two other hypotheses, besides that of Halley, which were once held in estimation,

tion, but which for some years, indeed, have been discarded. The first was that of Descartes, who was of opinion, that the water of the sea diffused itself in all directions under ground, and that, coming to the bottom of mountains, it there met with large caverns, into which, being rarefied by the central heat beneath, it ascended in vapours, leaving its saline parts behind, as being superficially heavier; and that these vapours, being impeded in their ascent by the tops of caverns, condensed there, forming small streams, or currents of water, like the steam in the head of an Alembic. The second supposes the sea water percolated through the pores of the earth, which, though large enough for the fluid to penetrate, were yet so small as to deny admittance to the saline particles which were commixed with them; which the water, during the course of its filtration, left behind, thus refining and purifying itself, till it became fresh and potable, before it mixed with the fountains of rivers.

But, it may be asked, if evaporation be not adequate to the causes already mentioned, why is not the main body of the ocean increased, by the prodigious volumes of water which have from the beginning of the world been falling into it? To this, there appears to me, to be but one reply. Some men are of opinion, that a quantity, for instance, equal to what flows into the Mediterranean, is consumed in exhalations every day. This seems, says Burnet, a hardy supposition; for if so much be consumed in vapours and exhalations, every day, as flows into the sea, what, if this sea had an out-let, and discharged by that every day, as much as it received? in a few days the vapours would have consumed all the rest; and yet we see many lakes that have as free an out-let as an in-let, and are not consumed, or sensibly *diminished* by the vapours. Besides, this reason is a summer reason, and would pass very ill in winter, when the heat of the sun is much less powerful: at least, there would be a very sensible difference betwixt the height of the water in summer and in winter, if so much were consumed every day, as this explication supposes. There are *subterraneous* channels for lakes and rivers, says he, why not for seas likewise? Surely, the cause is obvious. Why are we not to believe the very ocean evacuates itself by subterraneous out-lets? for, considering what an amazing mass of waters falls into it every day from the wide mouths of all the rivers of the earth, it must have out-lets proportionable, or it must have overflown.

LETTER XXV.

ALTHOUGH we have already bestowed some attention upon the agency of evaporation, it yet may not be amiss to examine it with a still greater degree of discrimination. Heat, as we have already observed, consists in the great velocity of the parts of matter; and the velocity of the particles of light, is the greatest of any. Hence, those particles, by their action, always produce the sensation of warmth: Particles of heat are constantly employed to separate parts of bodies, and by this means to produce exhalations. Thus, in the morning or evening, when the air is cool, we see the vapours arise from the earth; even our very breath becomes viſible, as it then wants a ſufficient degree of heat to rarefy the particles, and make them escape the sight. For it is proved by experiment, that all bodies looſe their parts, in proportion as they are more actuated by the power of heat; and when the degree of heat is very intense, there are but few bodies, whoſe parts are so fixed, or cohere so firmly, as not to be separated by its action.

In misty weather, we see frequently the mist of the morning intirely vanishing towards the the middle of day, and coming on again towards the evening; the reason of which seems to be, that the air being warmed by the approach of the sun to the meridian, is able to dissolve the morning mist; but as the air grows colder again towards evening, the water which had been perfectly dissolved by the midday heat, begins to be precipitated, the transparency of the air is destroyed, and an evening mist is formed.* Mists and dews will, generally speaking, be the greatest, when the difference between the heat of the air in the day time and at night is the greatest, because the hotter the day, the greater is the quantity of water which is dissolved, and the colder the night, the greater will be the quantity which will be precipitated.

Thus dews are extraordinarily heavy in hot climates. Who would suppose, that an acre of ground in England, even after having been parched by the heat of the sun in summer, could

* Bishop Watson.

could disperse into the atmosphere above 1600 gallons of water, in the space of twelve of the hottest hours of the day? no vapour is seen to ascend, and we little suppose, that in the hottest parts of the day, more usually ascends than in any other. But, that vapour which goes under the name of fog or mist, is merely that of a denser kind, which is too heavy to be immediately raised up into the air. The condensation of this vapour, is either owing to a greater degree of warmth in the surface of the earth and water, which throws it off in a greater proportion than common, and faster than it can rise through the atmosphere, or else, to the want of a sufficient degree of heat in the atmosphere, to attenuate those vapours, and increase their elasticity, and consequently their rarity.

Every particle, says Bergman, having a certain force of attraction for the principle of heat, forms a little atmosphere for itself. As long as these atmospheres prevent the particles from coming into contact, the whole remains liquid; when they are enlarged, the distances increase, and an expansion takes place, till at last, the superficial particles are resolved, by the necessary quantity of heat, into elastic vapour. At

212° the whole mass undergoes this change. The vapours then arise in great abundance, and produce the agitation of boiling. They exceed the bulk of the water 14,000 times, and then the vast surface is *able to absorb a far greater quantity of heat* than before. Is it not thus, that all evaporation produces cold? On the other hand, the excess of heat being gradually diminished by the coolness of the air, or in any other way, the bulk of the vapour is contracted, and the particles are condensed at last into drops of water.

But, evaporation is not solely effected by the mediation of heat.* Strong dry winds, in cold frosty weather, are often more powerful agents in promoting the evaporation of water and other fluids, than the greatest heat of the sun in summer. This vapour, however, or as it is meteorologically explained, this thin vesicle of water, or other humid matter, which ascends to a certain height in the atmosphere, there becomes suspended, till it returns in the form of rain, hail, or snow. An assemblage, or number of these particles, or vesicles of vapour, constitutes what we call a cloud; for we easily can conceive that mists and fogs are only low clouds, or clouds in the lowest region of the air, as clouds are no other than fogs raised on high.

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* Bishop Watson.

The ingenious Dr. Hamilton, some years ago, examined the subject of evaporation with considerable ability.* In all the accounts, remarks the Doctor, I have met with, fire, or heat, and rarefaction, by which watery vapours are supposed to become specifically lighter than air, are made to be the principal, if not the only causes of their ascent into the atmosphere. Dr. Niewentyt, and some others, supposed that the particles of fire, by adhering to those of water, make up moleculæ, or small bodies specifically lighter than air. Dr. Halley thought, that by the action of heat, the particles of water are formed into hollow spherules filled with a finer air, highly rarefied, so as to become specifically lighter than the external air. And Dr. Desaguliers ascribed the ascent of aqueous vapours, to their being turned into an elastic steam, and always rarefied more than the air by the degrees of heat, to which bodies are usually subject in the different seasons.

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* Philosophical Transactions.

But, to all these, I shall content myself, says Dr. Hamilton, with starting two out of a great many objections. First, if heat were the only cause of evaporation, water in a close room would evaporate faster than when exposed in a colder place, where there is a constant current of air, which is contrary to experience. Secondly, the evaporation of water is so far from depending on its being rarefied by heat, that it is carried on even while water is condensing by the coldness of the air: for water is gradually condensed by cold, till the moment it freezes; and since it evaporates even when *frozen* into hard ice, it must evaporate in all the lesser degrees of cold. Boyle, for instance, having counterpoised a piece of ice in a scale, hung it out in a frosty night, and found next morning, that it had lost considerably of its weight by evaporation. "Who "would have thought, says he, that so extreme-"ly hard and cold a body, would evaporate so "fast in the clear air of a freezing night?"— And since that time, others have observed the same thing. This fact seems to be an unanswerable objection to all the accounts in which rarefaction by heat is made to be the chief, if not the only cause of evaporation; and therefore we must have recourse to some other principle, to assist us in accounting for this phænomenon.

For my part, continues the Doctor, when I consider that the suspension of the particles of water in air, of salt in the waters of the ocean, and of other heavy bodies in the fluids that dissolve them, which seem to be phænomena of the same kind; I think we may reasonably suppose, that they arise from the same cause, and that what we call evaporation, is nothing more than a gradual *solution* of water in air. For as water contains a considerable quantity of air, so does air contain a considerable quantity of water, even when we think it quite pure and dry; as appears from the moisture drawn from it by dry salt of tartar, in such quantity, as to make the salt become intirely fluid. Now, since the air is an heterogeneous fluid, containing in it particles of another body, and yet retaining a perfect transparency, which is the criterion of a true solution in other cases; why should we not infer from analogy, that in this case also, there is a true solution of water in air? I admit that heat seems to promote solution, because it expands bodies, and thereby enlarges their pores, and lessens the cohesive attraction of their particles; so that a body, when hot, will more easily admit a dissolving fluid into its pores, and its particles not cohering together so strongly as when cold, will more readily quit each other, and unite themselves to the particles of the fluid by which they are attracted; and for the same reason, heat will also promote the evaporation of fluids. But even with this concession, I cannot conceive evaporation to be any thing more than a gradual solution of water in air, produced and promoted by the same means, by attraction, by heat, and by motion, as other solutions are effected.

The air, we know, says the Doctor, abounds with vitriolic and other acids, as is plain from the rusting of iron exposed to it. The lowest part of this air, then, being pressed by the weight of the atmosphere against the surface of the water, or by the currents of the winds, and continually rubbing upon it by its motion, has thereby an opportunity of attracting and dissolving those particles with which it is in contact, and separating them from the rest of the water. And since the cause of solution in this case, is the stronger attraction of the particles of water towards the air, than towards each other, those that are already dissolved, and taken up, will be still further raised by the attraction of the dry air which lies over them, and thus will diffuse themselves, rising gradually higher and higher, and thereby leave the lowest air not so much saturated, but that it will be still able to dissolve and take up fresh particles of water. And thus ice or snow will evaporate as well as water, its particles being attracted and dissolved by the air, which is strongly pressed against its surface.

But, however ingenious this reasoning, it is not to be taken altogether without limitation. Air may have in some instances the property of producing the evaporation of fluids; but there are other vapours which undoubtedly are raised merely by heat. Although the particles of fluids in common evaporation may be supposed raised into the atmosphere, by the attracting and dissolving power of the air, yet, in some particular cases, vapours will rise into the air on another account. For in some places, the earth often sends forth hot elastic vapours, that rise into the air by means of their elasticity, and carry up with them mineral and various heterogeneous particles. Fermentation generates elastic vapours, which expand themselves into the air. And the particles of water and other fluids, when sufficiently heated, acquire a repelling force, which separates them from the surface, and throws them upwards into the air.

But all these vapours soon loose that elasticity by which they were at first raised, and they must then be retained and kept suspended in the air, by the same power that keeps up all the vapours, which rise without any elasticity in common evaporation.

Against this theory of Dr. Hamilton, that vapour is no other than a true chymical solution of water in air, many difficulties were stated by different writers. Dr. Eeson, in particular, objects very justly, 1. That evaporation takes place in Vacuo. 2. That on this principle, clouds would be heavier than air by itself, and therefore, could not be supported at any height, in the atmosphere. 3. That we could have no rain, unless the air were supersaturated with water, as it would part only with what it could not retain in solution. 4. That though heat contributes very much towards converting water into vapour, which is again condensed by cold, yet, water spontaneously evaporates, and is suspended in the air in the coldest weather. Heat, observes this Writer, is the great cause by which water is converted into vapour; which vapour is found to be 1800 times lighter than our air, and therefore, must ascend, till it comes into a part of the atmosphere of the same density with itself. Heat is not to be considered in this process, as a transient agent: a quantity of it enters into chymical combination with the water, being essential to the constitution of vapour; and the watery particles are prevented from parting with this latent or combined heat, by the *electricity* of the atmosphere, for it is known from experiment, that electricity communicates to them a repulsive force with respect to one another; that it accelerates evaporation; and that the atmosphere is at all times electrified, not less in the night than in the day; more strongly in frost than in warm weather; in elevated than in low places; and as strongly near the surface of the earth in cold countries, as at considerable elevations in warm ones. And this seems a wise provision in nature, that the electric matter should appear near the surface in cold climates, to raise up and suspend the vapours, which otherwise would be condensed by the cold; whereas, in warm countries, the heat of the earth will be sufficient to raise vapours to a great height, which are afterwards carried still higher by the electric matter in the upper regions: and this perhaps is the cause why the air is so clear and transparent in warm climates.

With respect to the falling of rain, says our Author, two clouds possessing similar electricities, repel each other; but if the electricities are contrary, they attract and run together; the equilibrium is restored, and the power which kept them suspended is annihilated. A cloud passing over a high building or mountain, may in like manner be deprived of its electricity with or without thunder; hence, thunder showers among mountains, are so frequently partial, and confined to a small space. Fogs are produced by two causes, as different as their effects are opposite. 1. A precipitation of rain in very small particles. In this case, the air is moist, and wets the traveller's clothes; the stones of the street are covered with moisture, which often runs in large drops. 2. The absorption of moisture, when the air is too dry. This fact is well known to the inhabitants on the sea coast of Fifeshire, who, during the summer months, have frequent opportunities of observing a fog in the afternoon, driving up the Frith of Forth, with a drying east wind, which often blasts the trees and young vegetables, and therefore, in a small degree, resembles the *harmattan* in drying up the ground, and robbing vegetables of their moisture.

This hypothesis of the electrical agency in evaporation, was first started by Mr. Eeles in 1755. Neither impulsion, says he, rarefaction of the air, nor any attraction of the watery particles by expansion, is sufficient to account for the ascent of vapours. There is but one way, of altering the specific gravity of the particles of water, so as to render them lighter than air, the adding to each particle a sufficient quantity of some fluid, whose elasticity and rarety are exceedingly greater than that of the air. This is electricity. All fumes arising from fire, whether blazing or otherwise; all steams arising from boiling or warm water, and from all other fluids; the breath of man, and all other animals; and all the effluvia thrown off by perspiration, are strongly electrified: and hence, the ascent and descent of vapour and exhalation, attended by this electrical fire or fluid, is the cause of all the regular and irregular motions we find in the atmosphere.

An hypothesis so reasonable, and so capable of support, was readily adopted, and was soon strengthened by new observations, and by additional deductions. If the air be loaded, said the favourers of this doctrine, with common, or with electric fire, and thus loaded, be compressed by adverse winds, or by being driven against mountains; or condensed by taking away the fire that assisted in its expanding; contracting the air with its water, will descend as dew; or if the water surrounding one particle of air comes in contact with the water surrounding another, they coalesce, and form a drop, and we have rain. Those vapours which have both common and electrical fire in them, are better supported than those which have only common fire in them: for when vapours rise into the coldest region above the earth, the cold will not diminish the electrical fire, if it does the common. Hence, clouds formed by vapours raised from fresh waters within land, from growing vegetables, moist earth and other substances, more speedily and easily deposit their water, having but little electrical fire to repel and keep the particles separate, (common as well as electrical fire giving repulsion to their particles of water, and destroying the attraction of cohesion) so that the greatest part of the water raised from the land, is let fall on the land again, and winds blowing from the land to the sea are dry. On the contrary, clouds from vapours raised from the sea, having both fires, and particularly a great quantity of the electrical, support their waters strongly, raise it high, and being moved by winds, may bring it over the middle of the broadest continent, from the middle of the widest ocean.

These clouds driven against mountains, the mountains being less electrified, attract them, and on contact, take away their electrical fire, and from their frigidity, the common fire also. Hence, the particles close towards the mountains and towards each other, and fall. If much loaded, the electrical fire is at once taken from the whole cloud, and in leaving it, flashes brightly, and cracks loudly. When a ridge of mountains thus dams the cloud, and draws the electrical fire from the cloud first approaching it, that which next follows, when it comes near the first cloud now deprived of its fire, flashes into it, and begins to deposit its own water, the first cloud again flashing into the mountain: the succeeding clouds all act in the same manner. And hence the continued storms of rain, thunder and lightning, on the east side of the Andes, which running north and south, and being vastly high, intercept all the clouds brought against them from the Atlantic Ocean by the trade winds, and oblige them to deposit their waters, by which the vast rivers Amazon, la Plate, Oroonoko, are formed, which return the water into the same sea, after having fertilized a country of great extent.

Even a country without mountains, is yet not without means to make clouds deposit their water. For if an electrified cloud, coming from the sea, meet with a cloud raised from the land, and therefore not electrified, the former will flash its fire into the latter, and thereby each cloud will deposit its water. It is common to see clouds at different heights, passing different ways, which shows different currents of air. The air between the Tropics being rarefied by the sun, it rises; and the denser southern and northern air presses into its place. The air so rarefied and forced up, passes northward and southward, and must descend into the Polar Regions, if it have no opportunity before, that the circulation may be carried on. When it begins to descend in the Polar Regions, and gets in contact with the vapours arising there, the electrical fire they brought begins to be communicated, and is seen in clear nights, being first visible where it is first in motion; that is, where the contact to us begins, or in the most northern part: thence, the streams of light seem to shoot southernly, even up to the zenith in northern countries. But, though the light seems to shoot from the north, southerly, the progress of the fire is really from the south, northerly; its motion beginning in the north, being the reason why it is there first seen. Hence, the Aurora Borealis and the Aurora Australis.

As you have visited different sea coasts, you cannot but have remarked, that clouds continually arise at sea, and regularly direct their course towards the land, and especially the highest mountain. Some philosophers have ascribed this to an attractive virtue; but, besides that this occult quality, as we have already seen, is not in all cases to be implicity admitted, the mechanical cause of the phænomenon may be explained by material agents; namely, in addition to the electrical agency, the law of the equilibrium of fluids, by which the heavy air forces the lighter upwards; for continents, when under the same parallel, and of like elevation, being always more heated than s as, a constant current of air must take place, and drive the clouds from the sea towards the land. This direction will be the more constant, the more the mountains are heated. If the vapours meet with a flat and level country, they will glide over it, as we have said before, without

out stopping, because the land being equally heated, there is nothing to cause them to condense. This is the reason why it never, or but very rarely, rains in summer in Egypt, or the Desarts of Arabia and Africa.* The air of these countries being heated and rarefied, repels the clouds; and as it is the nature of all vapour to be elevated by hot air, they continue to float in the middle region, where the prevailing current carries them towards the higher parts of the continent: here, being at a greater distance from the surface of the earth, the great receptacle of heat, and being deprived also of their electric fluid, they are condensed, till their particles resolve into rain, hail or snow.

It is still, however, felt to be exceedingly difficult, to comprehend how the particles of water in the atmosphere, should want power to collect themselves into heavy drops, and fall downwards, rather than to remain suspended in the form of clouds or vapour, in those regions of the atmosphere which are *colder* than the surface of the earth.† It seems, says Cavallo, as if the particles of water in that state, were actuated by two powers: namely, their own attraction towards each other, and some other power, which prevented their coming so near as to be formed into water; but what that other power is, or how it acts, is still a mystery. Moreover, it is said, how is it possible to conceive that clouds, condensed into snow and hail, should be supported in the tracts of air, on the principles of comparative gravity? What mighty showers of hail-stones sometimes fall, so large even as not to be dissolved in a day or two. Now, either they must fall from an incredible height, the vapours by the way condensing, and as it were crystallizing them into ice, and in time augmenting them to that bulk; or else there must be some strange and unknown faculty in the air to sustain them. In truth, says he, the treasures of snow, and of hail, are among the secrets of Nature, upon which we may meditate with wonder and pleasure, but which we must never hope to explain.

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* Volney. † Cavallo.

But this, however respectable the authority, I cannot accede to; and my reason is this: air, when perfectly clear and transparent, as it is when in solution, receives very little heat from light; but, if cloudy, it is capable of receiving a certain degree, and hence cloudy air, and even clear air, is often warmer than certain kinds of earth, over which it is incumbent. Air is also often warmed by the condensation of the vapours interspersed through it, particularly when this condensation arises from electrical agency; and by these means, the upper strata of the atmosphere, are often warmer than those which are somewhat lower; and hence, the origin, as I conceive, of hail, which is rain condensed, by passing through air colder than that in which it was produced, and not, as the Cartesians imagined, the fragments of a frozen cloud, half melted, precipitated and congealed again. I suppose it will be generally allowed, says Doctor Franklin, that scarce any drop of water was, when it began to fall from the clouds, of a magnitude equal to that which it has acquired when it arrives at the earth; the same of the several pieces of hail; because they are often so large and weighty, that we cannot conceive a possibility of their being suspended in the air, and remaining at rest there for any time, how small soever; nor are we acquainted with any means of forming them so large, before they set out to fall. The air being 800 times lighter than water, is unable to support water even in the state of vapour. Hence, the water of a cloud is first formed into detached drops of rain, which falling through a colder region of the air, are there congealed in their passage, and increase in bulk in the short space of their fall.

A slight agitation of a fluid, as experiment shews, facilitates its conversion into ice, nearly in the same manner, as the slightest motion very frequently determines the crystallization of certain salts. And this arises, perhaps, from the circumstance, that by this means the caloric, which is interposed between the particles, and may oppose itself to the production of the phænomenon, may be expressed or disengaged. Thus hail appears to be nothing more than a confused crystallization. When it snows violently, and the atmosphere is not too dry, the air is observed at Moscow to be loaded with beautiful crystallizations regularly flattened, and as thin as a leaf of paper. They consist of an union of fibres which shoot from the same center to form six principal rays, and these rays divide themselves into small blades extremely brilliant. *

Hail and snow, therefore, are nothing but modifications of ice. The former, however, seems to be peculiarly produced by the *sudden* dis-

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* Macquart.

disengagement of the elastic fluid, which concurs in rendering water liquid, and is almost always accompanied with thunder. The very able and philosophic M. Chaptal of Montpelier, relates the following circumstance, of which he was an eye witness. On the 29th of October, 1786, four inches of water fell at Montpelier; a violent explosion of thunder, which was heard about four in the evening, and which appeared to be very near, caused a most dreadful shower of hail. At this instant, a druggist, who was employed in his cellar in preventing the mischief occasioned by the filtration of water through the wall, was highly atonished to behold, that the water which came through the wall, was instantly changed into ice. He called in several neighbours to partake of his surprize. I visited the place, says M. Chaptal, among the rest, a quarter of an hour afterwards, and found ten pounds of ice at the foot of the wall, and was well assured it could not have passed through the wall, which did not exhibit any crack, but appeared to be in very good condition. Did the same cause, which determined the formation of hail in the atmosphere, act equally in this cellar?

But the reconversion of air into water, which we lately touched upon, that is, as we are now to consider it, the formation of it into clouds and rain, has opened a new and a most pleasing field of investigation. De Luc is the philosopher who has the most minutely entered into this subject. This reconversion of air into vapour, is certainly curious, but the immediate cause, De Luc does not pretend to have discovered.* For though the cause of the transformation of vapour into air be given, says he, it does not follow that any analogy should obtain in the converse change. The theory of winds also, would appear from it, to be very frequently at least, a directly chymical effect. When a mixture of dephlogisticated and inflammable air is converted into water by the electrical spark, an explosion happens, that is, in becoming vapour, it expands into a large volume; and this vapour being condensed into water, a vacuum is left. It will therefore readily occur, what agitations must happen in the atmosphere, from the expansion which accompanies the formation of a cloud, and from filling up the immense vacuity produced by rain. It has long been a question, what becomes

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* Monthly Review, August 1787.

comes of the water that rises in vapour into the atmosphere, and in what state it subsists there, between the time of its evaporation, and its falling down again in rain? Various, as we have seen, have been the opinions; but De Luc contends, that the water which forms rain, though it has ever been considered and reasoned upon, as producing *humidity*, does not possess that property, and must, therefore, have passed into another state. The upper regions of the atmosphere, notwithstanding the continual ascent of vapours, and the diminution of heat at the same time, are *drier*, says he, than the lower: on the tops of high mountains a degree of dryness prevails, unknown on the plains. The air on mountains, likewise, is drier in the night than in the day.

On every hypothesis of rain from vapour, continues De Luc, as it is heat that produces the evaporation, so it is a diminution of heat that occasions the return of the vapour into water; and therefore, rain should happen only in the night, or at the coldest times of the day; whereas, experience shews, that it has no connection with heat or cold. And whatever the degree of heat be, as the air can part with only so much of its water as it is unable to retain in that degree of heat, no rain should be formed unless the air was saturated; and yet this is very contrary to observation.

De Luc's general proposition relative to clouds, is, that they do not arise from watery vapours, existing as such in the atmosphere; but, that they are formed in dry air; that they consist of bubbles of true elastic vapour, each coated with a watery film, like the bubbles in soap water; and hence, with *De Saussure*, he calls them vesicular vapour, whose particles may be distinguished by the eye, when placed at a proper elevation, with a dark ground of mountains or woods behind the cloud. These clouds are continually changing; they do not continue the same for two seconds together. Rain is never found, but when the vapour is produced too abundantly, and too rapidly to be dispersed by evaporation; the vesicles in this case, running together, and the water falling to the lower part, as it does in soap bubbles, till they become thin enough to burst. Another strong proof, that vapour must change its nature in the atmosphere, says he, is, that though evaporation continues for several months together on vast extents both of seas and continents, the air does not become moister, but on the contrary, more and more dry. Vapours must change their state, before they reach the tops of mountains, otherwise they would fill those cold regions with eternal fogs. It is by the conversion of the vapours into another state, into an aeriform fluid, that the mountains enjoy a transparent atmosphere, and that the rays of the sun, are permitted to reach the plains.

This theory, as you will perceive, is built upon the late supposed discovery of the *mutual convertibility* of water and air; a principle, undoubtedly, of most extensive influence in the œconomy of Nature. But, what is the particular species of this aeriform fluid, into which the watery vapours in the atmosphere are converted? Water appears, on the ground of late experiment (at least so it is asserted) to consist of dephlogisticated and of inflammable airs, deprived of great part of their latent fire, which is essential to the aerial state. Now, De Luc joining his idea of homogeneity of atmospheric air, to Mr. Cavendish's experiments, of *nitrous acid* being produced, while those two airs are decomposed in water, supposes atmospheric air to consist of these two, combined with that principle, which discriminates the nitrous acid from the other bodies of its class; so that atmospheric air, by being deprived of this principle and a certain quantity of its latent fire, becomes watery vapour or water; and water, by the union of fire, and the nitrous principle with it, becomes atmospheric air.

In all that we have yet said, however, on the subject of solution, and the consequently diaphanous state of the atmosphere, we have not touched upon one principle, on which both, but more particularly the latter, depend. Transparency and opacity are properties of matter. Light, in its passage, penetrates the porous vacuities, and is differently affected in its passage, as the units or atoms of matter are differently figured, and differently posited in regard to their pores. The rays of that uniform white light, by which all objects are rendered visible, proceed in strait lines; but, when the rays are broken and dissipated into a variety of directions, they no longer affect us with the same sense of light. When the interstitial vacuities of bodies are so disposed, that the light can preserve its rectilinear course through them, such bodies appear luminous throughout, and are visible in their internal substance; but when their constitution is such, as will not allow a free passage to the light, they are then visible only by those rays which are reflected from their surface, and their internal surface is opaque or dark. It may reasonably be supposed, that the atoms, or units, of which bodies are composed, being impenetrable in their nature, will be impervious to the rays of light, how subtile and powerful soever the light may be in its own nature.

The instance of the separation of the primary colours of light, which seems the most remarkable, is that of the rainbow. It is formed in general by the reflection of the rays of the sun's light, from the drops of falling rain, whose surfaces, as we have already seen, are convex (for if a small hole be made in a plate of metal, or other thin substance, and carefully filled with a drop of water, small objects may be seen through it distinctly, and as with a microscope, much magnified); though frequently it appears among the waves of the sea, whose heads or tops are blown by the wind into small drops; and is sometimes seen on the ground, when the sun shines, on a very thick dew.* Cascades and fountains, whose waters are in their fall divided into drops, exhibit rainbows to a spectator, if properly situated during the time of the sun's shining; as at the fall of Stauback, which you visited last year, on your way to the Glaciers of Griendelwald. Even water blown violently out of the mouth of an observer, whose back is turned towards the sun, never fails to produce the same phænomenon. This appearance is also seen by moonlight.

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* Nicholson's Philosophy.

The opposers of Newton's discoveries on light and colours, have strangely affirmed, that he taught that the rays of light were coloured. But, the error of this assertion, I need not point out to you. The air, we know, reflects the blue rays most plentifully, and must therefore transmit the red, orange and yellow, more copiously than the other rays. If the light of the setting sun, by passing through a long tract of air, be divested of the more reflexible rays, the green, blue, indigo and violet, the remainder, which is transmitted, will illuminate the western clouds with an orange colour; and as the sun sets more and more, the tract of air through which the rays must pass, becoming longer, the yellow and orange are reflected, and the clouds grow more deeply red, till at length the disappearance of the sun leaves them of a leaden hue, by the reflection of the blue light from the air. A similar change of colour is observed on the snowy tops of the Andes and Alps.

Between the parts of opaque or coloured bodies, are many spaces, as I have already said, which are either empty or replenished with mediums of other densities. Hence they become transparent, by filling their pores with any substance of an equal, or nearly an equal density with their parts. Thus paper dipped in water or oil; the *oculus mundi*, or hydrophanous stone, steeped in water; and many other substances, soaked in such liquors as will intimately pervade their pores, become by that means more transparent than otherwise. So on the contrary, the most transparent substances may, by evacuating their pores, or separating their parts, be rendered sufficiently opake, as salts or wet paper, or the *oculus mundi*, by being dried; horn, by being scraped; glass, by being reduced to powder, or otherwise flawed; and water, by being formed into many small bubbles, either alone in the form of froth, or by shaking it together with oil of turpentine, or some other convenient liquor, with which it will not perfectly incorporate.

But, I will here release you from this complicated subject. The height of the atmosphere, as I formerly explained to you, has never yet, and never can, in my opinion, be thoroughly ascertained. The elevation of vapours, however, is in some respects, precisely to be known. The height at which vapours freeze, says Buffon, is about 2400 fathoms in the torrid zone, and about 1500 fathoms in France. The highest clouds, continues he, do not rise above the level of the sea more than 3600 fathoms: hence, if our mountains were higher than they are, we should see in the torrid zone a belt of snow commencing at 2400 fathoms above the level of the sea, terminating at 3500, or 3600 fathoms, not on account of the cessation of cold, which augments in proportion to the elevation, but because the vapours would not rise higher. But, I shall have a good deal to say to you on this head, in some future letter; I shall now, therefore, conclude with just remarking, that the vapourous, or obscure part of our atmosphere, is only about the height of the 1980th part of the earth's diameter, as is evident from the height of the clouds, which is never above four miles.

LETTER XXVI.

THE sublime and yet beautiful process of evaporation, which relieves the earth from superfluity, and adorns our horizon with tints of the most glowing brightness, is yet, because not familiar to our senses, of apparently less consequence than that of *condensation.* The vapours which we have seen to rise, at length precipitate themselves in rain, in snow, or in hail. If on low lands, or on mountains, whose elevations do not reach to the freezing region, they glide away, or rush down in torrents. If, on the contrary, the Cordeliers, or the Alps, are their receptacle, they there concrete into solidity, and at their summer's leisure, but with ponderous dignity stream along the earth, for the benefit of the creation.

The larger, as well as smaller rivers, proceed either from a confluence of brooks and rivulets, or from lakes; but no river of considerable magnitude flows from one spring or one lake, but is augmented by the accession of others.

Thus the Wolga receives above two hundred rivers and brooks, before it discharges itself into the Caspian sea ; and the Danube receives no less, before it enters into the Euxine. Some rivers, those, for instance, in the country where you reside, are greatly augmented by the dissolution of the ice and snow. In the country of Peru and Chili, there are small rivers, it is said, that only flow in the day, because they are only fed by the snow on the mountains of the Andes, which is then melted by the heat of the sun. There are also, it is reported, several rivers upon both sides the extreme parts of Africa, and in India, which, for the same reason, are greater by day than by night. The rivers also in other places are almost dried up in summer, but swell and overflow their banks in winter, or in the wet season. Thus the Wolga, in May and June, is filled with water, and overflows its shelves and islands, though at other times of the year it is so shallow, as scarcely to afford a passage for loaded vessels. The Nile, the Ganges, the Indus, are so much swelled with rain, or melted snow, that they overflow their banks; and these deluges happen at different times of the year, because they proceed from different causes. Those that are swelled with rain, are generally highest in winter, because rain is usually then more frequent than at other times of the year; but if they proceed from ice or snow, which in some places are melted in the spring, in others in the summer, or between both, the deluges of the rivers happen accordingly.

The running of rivers, as I have already remarked to you, is upon the same principle as the descent of bodies on inclined planes; for it is as impossible for water, as for asolid body, to move on an horizontal plane; the re-action of such a plane, being equal and contrary to gravity, entirely destroys it, and leaves the body at rest. Here I speak of a plane of small extent, and such as coincides with the curved surface of the earth. But if we consider a large extent, or long course of water, then we shall find that such water can never be at rest, but when the bottom of the channel coincides every where with the curved surface of the earth. Hence, therefore, since bodies move on planes even in the smallest degree inclined, except so far as they are prevented by friction; and since the friction of the particles of water among themselves is inconsiderable, it follows, that the water situated on a plane ever so little inclined, will commence a motion; and if the plane be considerably inclined, and the quantity of water great, its velocity will be proportional, and its momentum such as will soon begin to wear away the earth, and create itself a course or channel to glide in. In artificial canals it is usual, I am told, to allow the fall of one foot in 300 yards.

Switzerland, perhaps of all countries in the world, is the most richly furnished with examples and demonstrations of the subject on which we are now engaged. The Glaciers alone are inexhaustible sources, to which we may apply for information. "The origin of glaciers," says De Saussure, their most enlightened historian, "is simply this: In the vallies of the high Alps, an immense quantity of snow is accumulated; not only because, for nine months together, all the water which in inferior regions falls in rain, there falls in *snow*, but particularly because the rapid shelvings of the mountains throw into their bosoms all the snow which is beat against them, but which they are incapable of retaining. "Les rochers nuds & escarpès ne pouvent pas retenir les neiges qui s'ent assient sur leurs flancs, elles glissent, & forment ces avalanches terribles dont nous parlerons ailleurs." The snows, accumulated by these two causes at the bottom of the higher vallies, condensed by their fall, and by the pressure of their gravity, remain without any alteration, until the heat of the sun, in summer, resolves a part of them : I say a part of them, for it is observed, that these avalanches which fall into the lowest vallies, scarcely can be melted by the heat of a whole summer; and consequently those which tumble into the uninhabitable vallies, can never undergo an entire dissolution. In the higher vallies, however, large masses of snow remain; the parts melted, and the rains, which the snow imbibes, becoming ice in winter, and exhibiting those porous glaciers, which are universally to be met with. From this," continues De Saussure, " it is evident, that the glaciers in the elevated vallies of the Alps have not been formed either by the congelation of great reservoirs of water, nor by the aggregation of laminæ of frozen water or icicles. All ice so formed is transparent and compact. On the contrary, the bubbles with which the glaciers are filled, shew manifestly, that they were snow which had imbibed rain, and which had been congealed, before the rain could have driven out all the particles of air which were contained in them. The experiment of artificially congealing wetted snow will prove this.

This consolidation of fluids, or rather the manner in which it is effected, has occasioned a good deal of dispute; particularly, as by experiment it has been ascertained, that water, for instance, impregnated with vitriolic acid, easily freezes, retaining all its air; which is the reverse of water impregnated with marine acid air, which will not freeze; and in another respect with water impregnated with fixed air, which in freezing parts with its air.* Philosophers, indeed, have never agreed as to the cause of this phænomenon. The Cartesians accounted for it by the recess, or going out of the etherial matter from the pores of the water. The Corpuscularians, on the other hand, attributed it to the ingress of frigorific particles, as they called them. Hobbes asserts, that these particles are nothing else than common air, which entangling itself with the particles of water, prevents their motion. Others will have a kind of nitrous salt to be the cause of congelation, by insinuating itself between the particles of water, and fixing them together, as it were, with nails.

Cold in general denotes the privation or absence of heat; and consequently those who suppose heat to consist in a brisk agitation of the component particles of the hot body, define

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* Priestley.

define cold to be such a faint motion of these parts, as is either altogether, or nearly, imperceptible to our organs of feeling; in which sense, cold is a mere term of relation between the cold body and the organ of sensation; and, in fact, the same body will be felt either hot or cold, according as the sensible organ is colder or hotter than it. Be this as it may, cold is found to have very considerable effects, and therefore should seem to be something positive. An intense degree of heat reduces most bodies, the hardest stones, even the diamond, to a fluid state. On the other hand, fluids are not only restored to their former solidity by cold, but greater degrees of it will congeal not only water in common, but the watery particles to be found in spirits.

The chain of our investigations has already led us to the assertion, that it is probable, all substances in nature would become solid, from the universal attraction of cohesion, were it not for the element of fire, which expands their parts, and prevents their positive contact. To this, however, ice may seem as an exception, because ice, or rather water converting into ice, powerfully expands, while, at the same time, it is said to part with its fire. This phænomenon, indeed, they account for, by saying, that water is a salt, and in *crystallizing* into ice, leaves greater spaces than were between the particles of water, which spaces being entirely filled with air, the mass expands, and becomes specifically lighter, though larger; but let this ice be pounded, and crammed so close as that the air shall be expelled, it will then manifest all the appearances and properties of contraction, from the want of fire.

The principal of all the cold ebullitions, chymically speaking, is the act of freezing. When water is congealed into ice, a great number of bubbles are produced in it, and imprisoned in the body of ice, where they are distinguishable to the sight, by reason of the transparency of the substance: and when the ice melts, all these bubbles are discharged at the surface. As these bubbles are produced in the act of freezing, the water is extended in bulk about one-tenth part, and with such a force, as no vessels are able to resist. And hence it is, that ice is specifically lighter than water, and floats with one-tenth part of its thickness extant above the water that bears it. "The bubbles so contained, in water, however," says Jones, "are not air;* it being impossible that air within such narrow

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* Philosophy of the Elements.

dimensions, should exert such an expansive force, unless, indeed, we should suppose it to be incredibly condensed, which is by no means the case; neither has the fluid, which is so collected, the properties of air. Besides, water, purged as much as possible of its air, by being first boiled, and then placed for many hours in vacuo, will yet freeze with the same collection of bubbles, and with the same force. It is not air, therefore, but the matter of fire, or that ether which is continually circulating through all things, and which is arrested in its passage through the water, when it is consolidated into ice: in a word, if a given quantity of water be frozen, and afterwards thawed, it will not fill the same vessel it would have done before it was frozen. It loses its weight by being changed into ice, by the incessant action of the air on its surface: by freezing it is likewise deprived of the greatest part of its air; and water, when saturated with air, is somewhat larger in bulk than when deprived of it. *

From what I have said above of the origin of glaciers, it might naturally be concluded, that accumulating always, that is, not melting away so much in summer, as they gain in growth in winter,

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* Bishop Watson.

winter, they would in time get to a most tremendous bulk. But, fortunately, nature has put bounds to their increase. During the summer, the sun, the rain, the hot winds, labour to destroy them; and evaporation, which has a considerable effect on ice and snow, particularly in an air rarefied, helps likewise, even during the greatest colds, to dissipate them.* But these causes only prevent, in a slight degree, the annual growth of snow and ice. Two other causes, more powerful, answer the end completely. One of these is the internal heat of the earth, which melts them even in the heart of the severest winters; the weight and consistency of their masses, and their excessive impenetrability to the action of cold, sheltering the surface on which they repose from the external atmosphere. The other is their gravity, which drags them, with a rapidity more or less great, into the lower vallies, where the heat of the summer is sufficient to melt them. Thus the more they accumulate, the more they act towards their own destruction. They increase in gravity, and consequently tend more to their fall; and increase in thickness, and consequently tend more to their dissolution.

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* De Saussure.

Our earth receives from the sun, and probably from other causes, as we have already noticed, which are not well known to us, a certain degree of heat, which is supposed to be universally the same at the depth of sixty or eighty feet, and to be unaffected by the variation of the seasons. This is what we here mean by the internal heat of the earth. * This heat acts continually on the inferior beds of ice, and causes *torrents*, which, even in the severest winters, are never stopped, from the great glaciers. " This," says De Saussure, " I proved on the spot myself in winter, at Chamouni, where the currents of water that issued were still very considerable, though certainly not so abundant as in the summer." On this resolution of ice into its former fluid state, Boerhaave observes, " That if a sudden thaw takes place after a long sharp frost, which has bound up the rivers, and penetrated the earth's surface to a considerable depth, it is, usually, quickly succeeded by a multitude of clouds and uncommon heats, and then by thunder and lightning. The reason," says he, " is, that the vapours and exhalations raised by the subterraneous heat, have long remained imprisoned under the covering of the earth; as appears hence, that if the ice of a ditch be broken in the middle of a severe frost, it presently emits warm vapours; and this the more plentifully, as well as the hotter, in proportion to the hardness of the frost, and the thickness of the ice. As soon, therefore, as the exterior frozen turf of earth is softened by warmth, the pent up vapours immediately escape through all the passages they can find, and mounting on high, form clouds, which being driven about, and sometimes illumined by the sun, produce such effects. Hence, the violent thunders in Muscovy, Sweden, and Denmark, after a thaw."

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* De Saussure,

But, this subject might be still further elucidated, by the known fact, that all substances, while dissolving, lose their phlogiston, which flies off in an aerial form, or in inflammable air. Hence, besides the laws of rarefaction occasioned by heat, bodies passing from a state of solidity to that of fluidity, always produce a cold, as salts dissolving in water; and hence also it is, that fluids capable of concretion, acquire a heat in becoming solids. "Heat," says Mr. Cavendish, "is generated in the congelation of fluids, and cold in the liquefaction of solids."

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The different degrees of heat and cold, however, with all their consequences on the element of which we are treating, as much as the difference of the seasons, depend upon the change of the position of the globe, with respect to the sun, the only visible fountain of warmth and life. The natural state of this globe, one would be inclined to think temperate. It is this warmth which secures springs from being frozen, few winters proving so cold, as to penetrate the earth, to more than twelve or fourteen inches beneath the surface. The transitions from heat to cold, in the air embracing our globe, are chiefly owing to the elevation and depression of the poles, which causes so great a change in the situation of the earth, that the obliquity and perpendicularity in which the rays of the sun fall, are continually in a state of variation. There are other causes indeed. Clouds will sometimes propagate heat by reflection, and sometimes they will propagate cold. Mountains too, and local peculiarities, will have a powerful effect. Under the equator, however, the sun in one hour moves fifteen geometrical degrees, or nine hundred miles. Under the tropic he moves the same number of degrees, but the degree there is only fifty-five miles, consequently he moves there but eight hundred and seventy-five miles in the hour, which is seventy-five miles less than under the equator. Moreover, we must consider that the sea has probably a property of conducting or diffusing heat and cold throughout its whole mass. But, this is not the case with respect to the land, as appears from the uniform temperature of springs near the surface of the earth: for water contained in wells not more than ten or twenty yards deep, varies nothing in its temperature, winter or summer.

A mistaken notion had long been entertained, that snow fertilizes land more than rain, in consequence of the nitrous salts which it is supposed to acquire by freezing. Snow certainly does fertilize. But the fact is, that rain water possesses more nitre than snow. * The agency of snow as a fertilizer in preference to rain, may admit a more rational explanation. There are two causes constantly acting upon the surface of the earth, the internal heat and the atmosphere. Different vegetables are able to preserve life under different degrees of cold; but all of them perish when the cold which reaches their roots is extreme. Providence, in the coldest

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* Bishop Watson.

coldest climates, has thus produced a covering for the roots of vegetables, and that covering is snow. The frost kills, when the snow does not protect: the snow likewise keeps in the internal heat of the earth: so that a kind of vegetation is carried on under the surface of snow.

And, now having advanced thus far; having seen water in a state of evaporation, then in due season precipitated, after this congealed, and finally dissolved; we shall next consider a few of these objects separately, in respect of several ascertained peculiarities. "Snow water," says Bergman, "contains a small quantity of salited lime, together with some slight vestiges of nitrous acid: this water, when newly melted, is totally void both of air, and of the aerial acid; substances which are found in almost all other waters; and hence it is, perhaps, that snow water is noxious to animals. Rain water is generally contaminated with the same substances as the former, but, in greater quantity. It is obvious that these waters, while suspended in the air, must collect and absorb the various heterogeneous matters with which the atmosphere abounds, and therefore, can never be obtained pure. Immediately after long continued rain or snow, these waters are found least loaded with heterogeneous matter. Spring water, when of the purest kind, contains but little heterogeneous matter; otherwise, we find in it aerated lime, salited lime, common salt, and sometimes a small quantity of alkali. Those springs which are called mineral, also contain gypsum, aerated and vitriolated magnesia, vitriol, aerated iron, &c. River waters are often so much purified by their motion, as to contain nothing more than aerated lime, common salt, and sometimes a little alkali. These are generally lighter than spring water, and the more pure, in proportion to the rapidity of their course, and the hardness of the bottom over which they run. Well waters, besides a large quantity of the above-mentioned substances, often afford gypsum and nitre. Lake waters are less clear than any of the former; they are also heavier, and deposit spontaneously some earthy sediment: they sometimes contain all the substances above recited; and besides, are generally vitiated by an animal or vegetable extract. Marsh waters have less motion, and therefore are less clear, more heavy, and more vitiated by extractive matter; hence they generally exhibit somewhat of a yellowish brown colour. Sea water contains common salt, vitriolated and salited magnesia, gypsum, and a considerable quantity of the putrid extract, which is generated partly from the innumerable crowd of animals which there live, die, and are decomposed, and partly from what is swept into it from the earth. Sea water has not only the strong taste of common salt, and the bitter one of salited magnesia, but it occasions a very singular nausea, which is frequently attended with vomiting. This nauseous ingredient is not to be found at all, or but very little, in sea water taken up at the depth of sixty fathoms, as experiments made upon water taken up at that depth evidently shew; the reason perhaps is, that the immense quantity of fishes, worms, and other animals, which inhabit the ocean, dying, are gradually, though not in complete substance, carried up to the surface, and there, by the assistance of the air, undergo a thorough decomposition, (at least this is the case with such parts of them as are soluble in water); and this putrefactive process is much assisted by the salt, which at the surface is present precisely in the quantity necessary to promote that operation. To render sea water, therefore, of benefit in times of exigency at sea, it would be right, were it possible, to take it up from the depth of sixty fathoms at least.

All the waters that we have thus enumerated, are to be examined two different ways; one by precipitants, and the other by evaporation. Soap, as you may have experienced, is not soluble in every kind of water: this is occasioned either by a disengaged acid, or by a large proportion of middle salt, with an earthy or metallic base. In either case a decomposition takes place; the acid unites with the alkali, and the oil is disengaged. Such waters as these are generally called hard waters, and are unfit for washing clothes, as also for boiling pulse, and the harder kinds of flesh.

Besides these more common and universal waters, there are those which I have already mentioned, that are significantly called mineral and medicinal; as for instance, the heated Bath waters, which owe their origin to the contact of common water with pyritæ, whose composition is iron, sulphur, and the vitriolic principle. Water in itself, is said to contain only three parts of latent fire, while the vitriolic acid is allowed to possess seven parts. These, however, coming into action with each other, draw out this latent fire, and give that degree of energy which causes heat. The interior parts of the earth, indeed, abound with all kinds of mineral matters.

The internal parts of the earth likewise abound with numberless caverns, cisterns, streams, and rivers of waters, which run every way through beds and strata of mineral, metallic, sulphurous, saline, mercurial, bituminous and oleaginous substances, carrying with them all the soluble parts of those bodies; and hence the variety of medical springs.* Streams of running water, passing by ignited or heated parts of the earth, become heated in various degrees; and hence warm and hot baths. In a word, all the superficial parts near the earth's surface, are replete with canals, resembling in some sort the circulation of fluids in an amimal body; insomuch, that some eminent philosophers, as we have already seen, have been ready to conclude that this earth we live on, is itself only a huge animal.

We have now, I think, touched upon every part of our present subject, worthy of attention, excepting one, and that is, the not very frequent phænomenon, of springs which run when the sea flows, and which stop when the sea ebbs. This, however, is not difficult to be accounted for, if it be supposed through the whole course from the sea, or from the river that is affected by the sea, to the mountain or plain where any of these extraordinary springs are, there is a channel into which their waters enter but little, the remaining part of it being filled with air only, because it is above the level of the sea: this being supposed, every time the sea flows, it rises up in this channel, and fills it fuller than ordinary; and as it rises, it drives along the air and vapours contained therein towards the head of the spring; whence, consequently, the water must run out. On the other hand, when the sea ebbs, the water in the channel descends. The ebb and flow of springs, which are also striking phænomena, are likewise to be accounted for on the simple principle of the syphon. Suppose a reservoir fed by a stream, whose water flows into another reservoir through a syphon, and which at the same time has another stream falling into the same reservoir, whose outlet or spring is still lower; the surface of this water, when the syphon works, will be suddenly raised, and press upon the water with a greater force; and consequently it will issue out with a greater velocity, and raise the surface if confined; but when the syphon intermits, the momentum will be less, and then the stream will ebb or decrease.

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* Martin's Philosophy.

LETTER XXVII.

THE waters which glide along the surface, and even those which rush through the vitals of the earth, have now passed under our contemplaon. But our task is not yet finished. Much as we may appear to have gone through, the greatest of our difficulties is yet to be surmounted. Let us return to the ocean. The ocean is actuated by two periodical motions called the flux and the reflux, or the ebb and the flow. The cause of the tides is supposed to be the attraction of the sun and the moon, but chiefly of the latter. The waters of this immense gulph, forgetful as it were of their natural quietus, move and roll in tides, obsequious to the strong attractive power of the moon, and to the weaker influence of the sun. The two tides of flood, and two of ebb, succeed each other alternately at about the interval of six hours; and happen later, nearly an hour each day than the preceding, owing to their exact correspondence to the motion of the moon, which daily culminates so much later. They do not, however, happen when the moon is in the meridian, but about three hours after, in consequence, it is said, of the greater force of the moon at that period, than when in the meridian; as the heat of the day is greater at three o'clock than at twelve, and the heat of the summer is greater in August than on the 21st of June. Lastly, the greatest spring tides happen not on the 21st of March and 23d of September, but in February and October, and for this reason, because the sun being nearest the earth in December, his influence is then the strongest, and so must hasten the time of the greatest vernal tides; and being weakest in June, the time of the autumnal tides will necessarily be retarded.

That the tides may have their full motion, the space in which they are produced ought to be extended from east to west 90 deg. or a quarter of a great circle of the earth at least, because the places where the moon raises most, and most depresses the water, are at that distance from one another. Hence, it is contended, it appears that it is only in the great oceans that such tides can be produced; and that in the large Pacific Ocean, they must exceed those in the Atlantic Ocean: hence also the reason is obvious, it is said, why the tides are not so great in the torrid zone between Africa and America, where the ocean is narrower, as in the temperate zones on either side; and from this also we are to understand, why the tides are so small in islands that are very far distant from the shores: for it is manifest, that in the Atlantic Ocean, the water cannot rise on one shore but by descending on the other; so that at the intermediate distant islands, it must continue at about a mean height, betwixt its elevation on the one and on the other shore.

As the tides pass over shoals, and run through streights into bays of the sea, their motion becomes more various, and their height depends on many different circumstances. The tide that is produced on the western coast of Europe corresponds to the theory above described: thus, it is high water on the coasts of Spain, Portugal, and the west of Ireland, about the third hour after the moon has passed the meridian; thence it flows into the adjacent channels, as it finds the easiest passage. One current from it, for example, runs up by the south of England, and another comes in by the north of Scotland. They take a considerable time to move all this way, and it is high water sooner in the places to which they first come; and it begins to fall at those places, while the two currents are yet going on to others that are farther in their course. As they return they are not able to raise a tide; because the water runs faster off than it returns, till by a new tide, propagated from the ocean, the return of the current is stopped, and the water begins to rise again. The tide takes twelve hours to come from the ocean to London bridge, so that when it is high water there, a new tide is already come to its height in the ocean; and in some intermediate place it must be low water at the same time. In channels, therefore, and narrow seas, the progress of the tides may be, in some respects, compared to the motion of the waves of the sea. It is also observed, that when the tide runs over shoals, and flows upon flat shores, the water is raised to a greater height than in the open and deep oceans that have steep banks, because the force of its motion cannot be broken upon the level shores, till the water rises to a greater height. If a place communicates with two oceans, or two different ways with the same ocean, one of which is a readier and easier passage, two tides may arrive at that place in different times, which, interfering with each other, may produce a great variety of phænomena. But the reasons why tides should be greater on coasts than in the open seas, says the celebrated Madame du Chatelet, are, "First, the water which strikes against the shores, and thereby forms a re-action, which must give them height; secondly, though it proceeds only with the imperceptible motion of the ocean, whose beds are very deep, it yet arrives in great quantities, and meeting with strong opposition, elevates itself considerably. Streights, and certain depths and positions of shores, affect it also in a very sensible degree.

Mons. Dassie, in a work published at Paris nearly a century ago, has been at great pains to prove that the sea has a general motion independent of winds and tides, and of more consequence than is generally supposed. He affirms that this motion is from east to west, inclining towards the north, when the sun has passed the equinoctial northward, and during the time the sun is in the northern signs, but the contrary way after the sun has passed the equinoctial southward; adding, that when this general motion is changed, the diurnal flux is changed also; whence it happens, that in several places the tides come in during one part of the year, and go out during the other; as on the coasts of Norway, in the East Indies, at Goa, Cochin-China, &c. where, while the sun is in the summer signs, the sea runs to the shore; when in the winter signs, from it. On the most southern coasts of Tonquin and China, for the six summer months, the diurnal course runs from the north with the ocean; but the sun having repassed the Line towards the south, the course declines also southward.* On this subject, or something that approaches very near it, we shall presently have much to say. We shall still continue, therefore, to attend to the general hypothesis.

The interval between the flux and reflux is not precisely what I have above said, six hours, but is about eleven minutes more.† So that the time of high water is about three quarters of an hour later every day, for thirty days, when it again recurs as before. And this answers exactly to the motion of the moon. She rises every day about three quarters of an hour later than the preceding one; and by moving in this manner around the earth, completes her revolution in about thirty days, and then begins to rise again at the same time as before. The time of high water, upon the day of every new moon, will at the same place always be found to be exactly at the same hour, and three quarters of an hour later every succeeding day. These alternate elevations and depressions of the ocean, are in such exact conformity with the motions of the moon,

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* Philosophical Transactions.

† Bonny-Castle's Astronomy.

that this planet has, with certainty, been considered as their cause. The effects of the disturbing forces of the sun and moon, likewise, depend upon their respective distances from the earth, as well as upon their particular situations. For the less the distances are, the greater will be the effects; and, therefore, as we have already seen, when the sun is nearer to the earth, as in winter, the spring tides will be greater than in summer, when he is farther off; and the neap tides on that account will be less. And for a like reason, as the moon moves in an elliptical orbit round the earth, and is nearer to us at some times than at others, the tides will at those times be greater, and at the opposite points of her orbit be less. Some variations likewise will be found to take place in consequence of the different declinations of the sun and moon at different times; for as they gradually decline from the equator, they lose their effect, and the tides become less; and when they are both in the equator, the tides of course become greater.

The cause of the tides was discovered, it is said, by Kepler, who explained it in the following manner: "The orb of the attracting power, which is in the moon," says he, "is extended as far as the earth, and draws the waters under the torrid zone, acting upon places where it is vertical, insensibly on confined seas and bays, but sensibly on the ocean whose beds are large, and where the waters have the liberty of reciprocration, that is, of rising and falling. Thus, the cause of the tides of the sea appears to be, the bodies of the sun and moon drawing the waters of the sea." Newton, on this idea also, erected his theory, but made it in a manner peculiarly his own, by discovering the cause of the tides rising on the side of the earth opposite to the moon; for Kepler believed, that the presence of the moon occasioned an impulse, which caused another in her absence.

In this theory, the sun's influence in raising the tides, is but small in comparison of the moon's; for though the earth's diameter bears a considerable proportion to its distance from the moon, it is next to nothing when compared to its distance from the sun. And, therefore, the difference of the sun's attraction on the sides of the earth under and opposite to him, is much less than the difference of the moon's attraction on the sides of the earth under and opposite to her; and therefore the moon must raise the tides much higher than they can be raised by the sun. On this theory, therefore, the tides ought to be, as I have above remarked, highest directly under and opposite to the moon, that is, when the moon is due north and south. But, we find that in open seas, where the water flows freely, it is not so; and the reason is declared to be obvious: for though the moon's attraction were to cease altogether when she was past the meridian, yet the motion of ascent communicated to the water before that time, would make it continue to rise for some time after; and much more must it do so, when the attraction is only diminished; as a little impulse given to a moving ball, will cause it still to move farther, than otherwise it could have done. Neither do the tides always answer to the same distance of the moon from the meridian at the same places, but are variously affected by the action of the sun, which brings them on sooner, when the moon is in her first and third quarters, and keeps them back later, when she is in her second and fourth; because, in the former case, the tide raised by the sun alone would be earlier than the tide raised by the moon; and in the latter case, later.

The moon goes round the earth in an elliptic orbit; and therefore in every lunar month, she approaches nearer to the earth than her mean distance, and recedes farther from it. When she is nearest she attracts strongest, and so raises the tides most; the contrary happens when she is farthest, because of her weaker attraction. When both luminaries are in the equator, and the moon in perigeo, or at her least distance from the earth, she raises the tides highest of all, especially at her conjunction and opposition; because the equatorial parts have the greatest centrifugal force, both from their describing the largest circle, and from the concurring actions of the sun and moon. At the change, the attractive forces of the sun and moon being united, they diminish the gravity of the waters under the moon, and their gravity on the opposite side is diminished by means of a greater centrifugal force. At the full, whilst the moon raises the tides under and opposite to her, the sun, acting in the same line, raises the tide under and opposite to him; whence their conjoint effect is the same as at the change; and in both cases occasion what we call *spring tides*. But, at the quarters, the sun's action on the waters diminishes the effect of the moon's action; so that they rise a little under and opposite to the sun, and fall as much under and opposite to the moon, making what is called *neap tides*, because the sun and moon then act obliquely to each other.

In winter, the sun being nearer to the earth than in summer, is of course nearer to it in February and October than in March and September; and therefore the greatest tides happen not till some time after the autumnal equinox, and return a little before the vernal. When the moon is in the equator, the tides are equally high in both parts of the lunar day. But, as the moon declines from the equator towards either pole, the tides are alternately higher and lower. The sea, however, being thus put in motion, would continue to ebb and flow for several times, even though the sun and moon were annihilated, or their influence should cease; as if a bason of water were agitated, the water would continue to move for some time after the bason was left to stand still; or like a pendulum, which having been put in motion by the hand, continues to make several vibrations without any new impulse.

This is the theory of the tides, and a beautiful one it is. But, it is not the growth of modern days, as has been conjectured. It is of old and venerable date, but greatly improved upon. Cleomenes, a Greek writer upon metereology, speaks with great extent and precision upon this physical subject. " The moon, according to her different appearances," says he, " not only causes great revolutions in the air, over which she has the power, and produces many serviceable effects, but she is also the cause of the flux and reflux of the sea."* And the great naturalist, Pliny, would seem even to speak in the words of Kepler or Newton. He contended, " that the sun and moon had reciprocally a part in the cause of the tides;" and after a succession of years of observation, he explicitly affirmed, " that the moon acted strongest on the waters, when she was nearest to the earth, and that the effect of her action was not sensible to us, till some time after it had happened."†

With such masters to teach and to confirm us in one general and well constructed doctrine, it may appear almost prophane to deviate from the prescribed rule, and to hazard any other hypothesis. But, truth is not to be sacrificed at the shrine of adulation; for Newton himself tells us, that propositions obtained from phænomena by induction, ought to be held, notwithstanding any opposite hypotheses, as strictly, or very nearly true, until other phænomena have occurred, by which they may be rendered either more accurate, or more exceptionable.

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* Philosophy of the Elements.

† Recherches sur l'Origine des d'Ecouvertes attribuées aux Modernes.

Nor should it be forgotten, however revered and transcendent the names of those illustrious characters, whose labours have afforded us the means of encountering their doctrines, that venturing upon a rational argument, men do no more than what fairly belongs to them. No honest creed, either in philosophy or religion, forbids enquiry. It is unworthy the character of reason, to shrink from the exposition of what may even delusively appear error.

The force of attraction, say the favourers of the above hypothesis, increases in proportion as the square of the distance diminishes. But, have we not a multitude of masses much smaller, and that have much less substance than the waters of the ocean? The waters of the ocean are, however, pulled up and attracted into large heaps, twice a day, at no inconsiderable distance from the earth, under the influence of the moon. The superiority of the terrestrial attraction does not hinder them from experiencing, in a small degree, the impression of the lunar attraction; whereas there is no ebbing or flowing for *us*: we still adhere to the surface of the globe.* Is it not fair for us, therefore, to think that this attraction, as relative to the ocean, is a cause of not the most undoubted validity, but one that fills up the vacancy of what is not understood, and which indeed avails us very little, though it were readily to be calculated? Or if it should be to be supported as a matter of fact, it surely cannot be criminal to ask, why this cause has so much predilection for the waters of the ocean, and so little influence upon other substances which would seem as obedient to its power?

Systematic philosophy, however beneficial, is not unfrequently involved in difficulty. It refuses, for instance, in some opinions, influence to the moon either on animals or vegetables; and yet it gives her a most powerful influence on the waters of the ocean. It is still more contradictory, it allows the ocean to be so affected as to have tides; and yet it will not admit, that it acts with any sort of power on lakes, or on inland seas. Their inconsiderable extent, surely, ought not to exempt them from the influence of gravity. The lakes of America are not all so small, that when the moon is vertical, she can attract every part alike, and therefore rendering all the parts equally light, no part can be raised higher than another. But, if this were the case with the lakes, it is not so with respect to the Mediterranean and Baltic seas. It is true, the principal motions of the sea arrive, in our hemisphere, at the same time with the principal phases of the moon; but from this, it should not be too arbitrarily concluded, that the tides are *occasioned* by that luminary.* One circumstance, indeed, would seem to prove to demonstration, that it is not this influence alone at the equator which causes the tides. The tides between the tropics are *less considerable* than those in the higher latitudes.

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* L'Abbè Pluche.

I am aware, that the lunar influence is not denied by all physicians, to the animal and vegetable kingdoms. Hippocrates, in his Crises, seems to refer to it. Many others have given into the same opinion:† and the idea is far from extravagant, for air being lighter than water, and the surface of the atmosphere being nearer the moon than the surface of the sea, why should it not be admitted, that the moon raises much higher tides in the air than in the sea? Dr. Balfour, indeed, from upwards of twenty years close and accurate observation, and with an ability which is acknowledged, has no hesitation in declaring, that without pretending to explain, or say whence it proceeds, where it exists, or how it operates, there is what he modestly, and guardedly, calls a *sol-lunar* influence, which affects the constitution of man, particularly in the acquiring, and in the progress and termination of disease; and which, from the paroxysms it constantly and invariably produces, there can be no difficulty in denominating tides of the animal œconomy. "There is," says he, "a rising and falling in its force and action, nearly coincident and similar to that of the flowing and ebbing of the tides; the former appearing towards the end of the interlunar interval, and continuing until the expiration of the lunar period; the latter appearing upon the expiration of the lunar period, and continuing until towards the end of the interlunar interval." It is in an extraordinary manner even to be traced in full analogy, through the springs and neaps, and in a more marked way, perhaps, at the equinoxes. "The natural tendency of certain fevers, for instance," says Dr. Balfour, "is to make their attack, to increase in their violence, and to continue during the lunar periods; and on the other hand, to defer their attack, to abate in their violence, and to subside in the interlunar intervals." Do not we see regularly stated monthly revolutions in certain classes of beings, and accidental ones in others? And may not this influence, in fair deduction, be believed to be the celebrated *vis medicatrix naturæ*, the producer of paroxysms, the giver of remission, the deity of some physicians, and the devil of others? In regard to animals, birds, and fishes, their constitutions seem evidently to undergo a regular change, corresponding with the revolutions of the moon. This has been established by the observations of every age, and in every quarter of the world. With respect to vegetables, Dr. Mead says, "Husbandmen are regulated by the moon in planting and managing trees; and considerable effects are ascribed by farmers to the full moons of harvest, which cannot proceed from any increase of heat communicated by the lunar rays."

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* Les Etudes de la Nature.

† Drs. Mead, Lind, Jackson, and Balfour.

Thus you see, how extensive the support of the lunar influence is, and how very pleasingly all the branches of the theory hold together. Yet, though I can, as readily as any man, acknowledge the sun, mediately and immediately, to exert a boundless dominion over every production, and in almost every operation and revolution of nature, I yet cannot, with equal facility, and with the same conviction, implicitly yield an acquiescence to a superior faculty in the moon. I will not detain you with the many arguments, which have been used, to prove the moon to be without an atmosphere herself, although her attractive energy is so potent as to regulate ours; nor with the strong reasoning with which clouds and rain are denied to the lunar regions, although they have waters for evaporation, and an ocean, it must be allowed, as easily to be operated upon, as that we have upon the surface of our earth, and which is at so great a distance. It is somewhat singular, that the satellite of this globe, notwithstanding her insignificant dimensions, and her borrowed force, should be thus allowed the place of supremacy; and though in general phænomena she be denied every thing, yet that in particular phænomena, she should be given every thing; especially, also, when she is acknowledged to be so peculiarly situated, that the attractive power of the sun is to be considered as equal on her, as it is on the earth. The influence of the moon thus, I cannot, I confess, conceive in any manner adequate to the extraordinarily coincident ebbs and flows in the general fluids of nature. The moon, indeed, I will readily grant, may be looked upon as the *index* which unerringly points to the tract, or to be an intervening rotatory object, which may, in its revolving situation, obstruct the influence of the sun; but, the spring, or the motive power, I must be of opinion, is inherent in some other source. Let us try if it be not so.

In tracing the origin and the succeeding increase and diminution of rivers, the periodical, or rather I should have said, the constant though unequal melting of the snow gathered on the tops of mountains, and in glaciers consolidated in the valleys, has appeared to be an agency of infinite importance. As the liquefaction of these masses increased from the influence of heat, we have seen the torrents accelerated in their stream, the rivers swoln and elevated in their surfaces, and even these continued in their vigour, until the gradual decrease of the originating cause had reduced them to an ebb, as the increase had impelled them to a flow. Will not analogy then present us here with something like a clue, if we turn our eyes, without prejudice, towards the enormous glacial masses of the poles? Let us attend to this subject a little; and for a guide, let us follow the deductions of the benevolent and scientific Saint Pierre.* Taking him as our guide, we shall at least have the advantage of searching after truth, upon principles which are far from being occult; and if we do not arrive at certainty, shall at least be amused during the progress of our enquiry.

"I reduce," says this worthy man, "all the tides of the ocean to *two* grand causes; and those from the dissolution of the ice, which I derive from the poles. The masses of ice formed in our hemisphere in the winter months, form an arch which is more than two thousand miles long, and whose thickness in Spain indeed is only a few lines, in France a few inches, in Germany some feet, but in Russia is many fathoms, and so mounts up to many hundreds of feet in the vicinity of the poles. From the spot where ice commences, it grows as it were

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* Les Etudes de la Nature.

in regular and progressive proportion to the poles." What enormous heaps of solid waters must be thus generated by the winter! So far beyond all calculation, so tremendous must they be, that even though the dissolving supposition should be visionary, there yet would result from the polar periodical dissolutions, an increase of quantity in the ocean, sufficient at least to account for some of the phænomena of the tides.

The southern hemisphere has a still greater quantity of ice. — From two such volumes of indurated water, what effect may not be derived? Gravitation, and the attraction of the sun and moon, are indeed favourite and accurate philosophical words; but are principles too arbitrary, and of too concealed import, to render us entirely inattentive to the evident and palpable elucidation, arising from a melting glacier, of four or five thousand miles long, and three times as much in circumference.

In 1746 and 1747, Ellis observed with astonishment, in his voyage to Hudson's Bay, that the tides came from the *north*, and that they increased, instead of being diminished, as he advanced in his latitude. This, so contrary to our ordinary tides, which come from the south, led him to conjecture that they did not come from the Line, nor from the Atlantic Ocean, but, that the phænomenon was to be attributed to the communication, which he supposed to exist between Hudson's Bay and the Southern Ocean. In latitude 65 deg. 37 min. the tide he found to run at the extraordinary rate of from eight to ten miles per hour.

The melted ice, which thus spreads from the north of America, and from the north of Europe, during the months of July and August, must indisputably act as an auxiliary, if it does not entirely contribute to the giving us our spring tides in the September equinox. For when their further effusions are stopped in the month of October, is it not then that our tides begin to diminish? It may be asked, why the tides come from the north, and the east, in the northern parts of Europe and America; and why they should come from the south on our shores, and those of America, which are in the same latitude? An observation of Dampier may be given as a reply to this. That ingenious navigator made this short distinction between currents and tides: "Currents," says he, "are only experienced in open seas, but tides are on coasts." May not then the effusions from the northern pole, which are the tides from the north and from the east, to those parts which are in the neighbourhood of the pole, and to the bays which communicate with it, be supposed to take their general course towards the Atlantic Ocean and the Equator, drawn thither by the diminution of the mass of waters, occasioned by continual evaporation in the torrid zone? Even the masses of ice, themselves, are observed to move towards warmer climates: they have been met with, to my own knowledge, five hundred feet high in forty-one degrees south, five miles in circumference, and Farenheit's thermometer sixty degrees; and this proves either a strong current, an attraction, or some other cause, acting regularly and systematically.

" By the general though not perceptible current, however, of these polar effusions," says Saint Pierre, " they may be said to produce two counter currents, or positive hydraulic reactions, as is observed frequently in bits of straw, at the sides of streams, mounting upwards against the course of the streams." Are not boats found very remarkably to profit by these lateral counter currents? Le Pere Charlevoix, talking of counter currents in the lakes of America, says, "Ces grands courans, ne se font sentir qu'au milieu du canal, et produisent sur leurs bords des remoux ou contre courans, dont on profite quand on va terre a terre, comme sont obligès de faire ceux qui voyagent en canots d'ècorces." Even in the lake of Geneva, I have been informed that there is a lateral flux and reflux in summer towards the evening, and this occasioned by the increased dissolution of the snow and ice of the Glaciers.

The general current, which flows from our pole in summer, and which may be supposed to spread rapidly, traverses the Equinoctial Line; for it is not then stopped by the effusions of the southern pole, the more extensive dominions of that pole being one vast and hoary region of ice. In the same manner, it may be presumed, it stretches beyond the Cape of Good Hope, though a strong westerly set towards the Equator is generally prevalent round the Cape; and taking its direction thence from the position of Asia and Africa, it forces the Indian Ocean to take its direction with it, contrary to its ordinary motion. And hence, perhaps, one first cause of the *monsoon current*, which takes place in the Indian seas in April, and which does not finish till September. The other monsoon is of course caused by the cessation of this general current from the north, and the commencement of the opposite one from the south.

By these polar effusions, therefore, the principal phænomena of our tides, I am strongly inclined to believe, may be accounted for. One sees, for example, why those of the evening in summer, are stronger than those of the morning; because the sun acts more powerfully in the day, than in the night, on the glaciers of our pole. In springs from mountains covered with snow, the same thing is observed. They flow more abundantly in the morning, than in the evening. This shews us the reason, likewise, why our tides in the morning in winter, are more considerable than in the evening, and why the order of our tides changes about every six months. At each pole, the sun continues half a year without setting in summer; at the same time, it is true, he never ascends above, nor descends below the horizon, more than twenty-three degrees and a half. The polar inhabitants, however, never see the full moon in summer, though they have her always in winter. Nor do they see the sun in winter, though they have him always in summer. In which of these periods, then, is the strongest tide in the ocean? Ellis answers as above: "towards the northern pole in the summer." But, is it by attraction, or by effusion, that the tides of the ocean come from the poles? And why is not a polar effusion, from nearly a quarter of the bulk of the whole globe, of ice, to be admitted as capable of spreading to shores at four or five thousand miles distance, as a mountainous effusion from an Imaüs, an Andes, or an Alps, is known to be capable of a two and three thousand miles run, from their sources to the sea? The current of the ocean, not being visible, does not afford the slightest objection against the hypothesis. In whatever manner a mere negative may be supposed to militate against a polar effusion, in like manner, and with equal strength, it militates against a fluvial progress by atraction. In open seas, the tides in general rise but to very small heights, in proportion to what they do in wide-mouthed rivers, opening in the direction of the stream of tide. For, in channels growing narrower gradually, the water is accumulated by the opposition of contracting banks: like a gentle wind, little felt on an open plain, but, strong and brisk in a narrow pass; and especially if the wider end of the pass be next the plain, and in the way of the wind. The Atlantic does not shew any current tending particularly to the Mediterranean, though it is always rapidly running into the Mediterranean, through the Streights of Gibraltar. The like is the case with the Black Sea, before it rushes through the Dardanelles.

But, let us consider a few other affinities which lie between the poles and the sea, and which we shall find more surprising, and even still, perhaps, more convincing. It is at the *solstices* that we have the lowest tides in the year; and it is at the same periods that the most ice is at the poles, and consequently the least water in fluid is in the ocean. The solstices, you will remember, are two in each year, the æstival or summer solstice, and the hyemal or winter solstice. The word, you know, means the sun's arrival at his greatest distances from the *Equator: the summer solstice is, when the sun seems to describe the tropic of Cancer, which is on the 22d of June, when he makes the longest day: the winter solstice is, when the sun enters the first degree, or seems to describe the tropic of Capricorn, which is on the 22d of December, when he makes the shortest day. This, of course, is to be understood of our northern hemisphere; in the southern, it is just the reverse. But, the plain reason why at the solstices we have the lowest tides, is this: the winter solstice, with us, is the period of the greatest cold, and there consequently is then the greatest volume of ice in our hemisphere. It is true, it is the summer solstice at the southern pole; but there is very little ice then melted at the southern pole, because the action of the greatest heat is not as yet felt there; as indeed we experience in a similar case ourselves, for we find it is not until the earth has acquired a considerable degree of heat, joined to the immediate action of the sun, which does not happen till six weeks after our summer solstice, that we have the hottest days in the year.

The contrary, however, to this, the highest tides, we certainly have at the equinoxes; for it is then there is the smallest quantity of ice at the poles, and consequently the greatest quantity of water in the ocean. For, as it has been calculated, the earth and the sea, which is covered by ice, may be equalled to one tenth part of the whole ocean; and the height of the polar ices, from their base to their top, is at least six hundred feet: a mass, which, in melting, must necessarily add *one tenth* to the level of the ocean, that is, sixty feet, which we will reduce to fifty, to make allowance for the difference between the volumes of ice, and of ice when melted into snow.* At the equinox in September, the greatest part of the ice at our poles, which has been worked upon during the whole summer, is melted; and it is at the same time also, that the ice at the southern pole begins to thaw. You will observe, however, that the tides at the equinox in March are higher than those of September; and this proceeds from its being the end of summer at the southern pole, which has a greater mass of ice than the northern, and consequently gives a greater volume of water to the ocean. The reason of its having more ice is, that the sun continues six days longer in the northern, than in the southern hemisphere. The *intermissions*, however, between these polar effusions, and which of course, must be supposed to cause the flux and reflux of our tides, twice in the course of the four and twenty hours, may probably depend on the melting of the ice during the course of the day, and the cessation, or the inconsiderableness of thaw, during the night. And the difference of three quarters of an hour in the tide may also be occasioned by the difference of quantity in the body of the ice, as it progressively recedes towards the pole, and as, in its daily thaw, the line of congelation gets farther from us.

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* Physique du Monde.

From all this then it appears, it is not from the exclusive action of the sun and moon between the tropics, that the tides are to be deduced; but that it is to the influence of these luminaries at the poles of the world, we are to look for their principal source. The polar effusions may be, in a considerable degree, the real causes; and as the phases of the moon are co-ordinate with the course of the sun, which creates those effusions, the reason is clear, why the tide and the phases of the moon, should happen at the same time. In a word, the tides are semi-diurnal polar effusions, as the general currents of the ocean are semi-annual. I say, the two general currents in the year, because the sun in turn warms each of the two hemispheres during the progress of our annual revolution.

"Providence thus," says Saint Pierre, "has probably ordained, that the effusions from the polar regions should be in proportion to the evaporations from the ocean. And hence, we may consider the two hemispheres of the earth, as two mountains; the two poles, as the icy summits of these mountains; and the seas, as the rivers which majestically flow from them. And if we compare the proportions of the glaciers of Switzerland with their mountains and with their rivers, we shall be able readily to form an idea of the polar glaciers, and of the oceanic rivers, which they send forth. The tides, indeed, are twice in each day. But, this is to be accounted for, as I have already said, from the sun, in his progress during the twenty four hours, heating both sides of the polar ice. In lakes, in the day time, there is a sort of flux and reflux. Nor is it to be doubted, that if the sun, during the course of the night, could heat the opposite sides of the mountains whence lakes are derived, they would also have a similar flux and reflux to that of the sea. In all this, however, we are not to suppose that each day's tide is the same day's effusion at the pole. It is only the effect of a course of such effusions, which perpetually succeed one to another; and the time, which any diurnal effusion at the poles takes in passing to us, may be estimated at six weeks.

LETTER XXVIII.

THIS simple and plain deduction of the tides of the ocean, from the glacial effusions at the poles, is too novel, and too unfriended, I am afraid, to be generally adopted. Yet it bears itself up, with a wonderful appearance of probability. The origin of the flow of rivers from masses of ice, support it by analogy; and the phænomena of the spring and neap tides are accounted for, both by reasoning and by calculation. In the main of the ocean, for instance, it is proved that there are in general no tides. In the Caspian Sea, which is about 860 miles long, and and in one part 260 miles broad, there are no tides, though there are strong currents. In the Baltic, there is no regular flux nor reflux. There is no tide in False Bay at the Cape of Good Hope, which has the aggregated masses of the Indian, Southern, and Atlantic Oceans. The same may be said of the Mediterranean, excepting in a few particularly situated spots, although in the Adriatic there is a flux and reflux. Why are the first of these considerable masses of the general body of the waters never raised, and the others always raised? And why is it, as Addison says, and as I have before remarked, that in summer, the lake of Geneva should have something like an ebb and flow, which arises, as it should seem, says he, "from the melting of the snow, that falls into it more copiously at noon, than at other times of the day?"

These striking deviations from, or rather contradictions to the received theory of the tides, argue with me, strongly I confess, against the infallibility of the doctrine. I cannot but think we may have imposed upon ourselves, when we have abstractedly given the phænomena of tides, to the operating energy of causes arbitrarily imagined. However the phases of the moon may accord with the swellings of the water, may not both one and the other be looked upon as harmonious and co-ordinate effects of another distinct but powerful principle? What is the augmented quantity, or rather the increased elevation of the main body of the ocean, at the moment of a spring tide? Nothing comparatively speaking. Does not the fact then seem to be, that it is not the mass of the ocean, which is diurnally *raised*, but, that it is the volume of the waters which is diurnally augmented? An increase of a fluid, we know, occasions an uniform augmentation in every direction. But, before it gets to its general level, should opposing bodies intervene, those opposing bodies which would otherwise impede its progress, must experience a considerable change in appearance from its unusual elevation. The shores of the northern and southern hemispheres may be considered as opposing bodies of this nature. The shape of the shores, indeed, and the depth of the beds of the rivers, will determine the greater, or the lesser height of the waters at their influx. For instance, in the Severn, the tides do not rise higher than a few feet; whereas in the Wye, whose tides are immediately derived from the Severn, they rise to the extraordinary height of sixty feet. Can this be occasioned by any thing else, than a difference in the planes of the beds of these rivers? In a word, to my apprehension it appears, the swelling of the ocean, by the joint attraction of the sun and the moon, is less physically intelligible, than the periodical effusions of the polar ices: and more especially, as we experimentally know, that the sun's attraction of a fluid, occasions its *evaporation*, not its elevation; and that the influence of the moon, if it has any, is at best but problematical, and feeble in its operation.

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It has, indeed, been said, that the lunar energy has been demonstrated, beyond the power of contradiction; and that besides its wondrous influence on the element of the waters, it can be further, and perhaps more clearly proved on the element of the air. This is going a great way. Give such energy, indeed, to the sun, and I am satisfied. But, if one be erroneous, the other must be erroneous. Or if one be true, the other must be true; for the ocean of the fluid air must be affected as well as the ocean of the fluid water, and in a considerably greater degree, as it has eight hundred times its levity.

Upon the whole, then, the theory of the polar effusions, seems to me, to have less difficulties attached to it, and to demand less implicit faith, than the theory of the solar and lunar attractions. I may, indeed, be wrong; but, I honestly confess, I cannot comprehend how tides in the air, tides in the brain, or tides in the ocean, can, in any specific manner, be brought about by lunar attraction. I am well aware of the great names, from which I venture to differ. On many occasions, I have shewn my thorough belief of a tendency in the particles of matter to each other, or of an attraction; for I admit the word, knowing no better. But, whether attraction be cause or effect, I profess myself entirely ignorant. The attraction that lifts up the tide, is the occult, the contradictory attraction, I may say, that I have alone presumed to call in question. For upon what principle of reason can I suppose the enormous body of the ocean to be powerfully affected by the attraction of the moon, and that other given quantities of water, such as seas, lakes, ponds, even basons of water, shall in no manner whatever be affected? Is an attractive cause to have great influence over a large body, and no influence over a small body? But, enough. You have here, candidly, what has occurred to me on the subject. Should I be in an error, it is my only wish to be set right: and I shall be grateful to the friendly hand, which shall point out to me where I am wrong, and shall hold forth further light, to illuminate the path in which I delight to tread.

LETTER XXIX.

FROM water in its fluid and in its elemental state, we now proceed to consider it as the region in which a variety of our most stupendous terrene substances have been gathered together, or crystallized. The liquid ocean has been the parent of the solid rock, whose conformation, together with its various phænomena, evidently shew it to have once been soft or liquid; for substances that are found in it, could not have entered into it, after it had become hard and impenetrable. Des Cartes, indeed, thought it not too much to say, "the rock differed in nothing from common metal, but in the grossness of its elementary particles;" while Tournefort, on the contrary, held, "that stones, like plants, were generated from a seed." An appearance of veins, which he observed in certain stones, as well as the stalactitical increase of the inscriptions on the famous grotto of Antiparos, led him to conclude, they were really of an organic structure. But it is now, I believe, granted on all hands, that stones do grow, by the concretion

tion of terreous and other particles, which, according to their mixture, make either adamants, pebbles, or free-stone. Osseous and testaceous substances, likewise, harden by time. Their durability, however, is not eternal. Like other things that have growth, they have decay. Were it otherwise, were stones continually to increase, and be sensible of no decay, the whole world would have been turned, by this time, into one massy rock, by petrificaions. But, air and rain work upon those parts that are exposed; and fire upon those that are imbedded. They crumble perceptibly, and in the succession of ages, inevitably have an end.

Every production of an animal, vegetable, and mineral substance, is progressive; plants and fruits, from seeds; and stones and minerals, from the bowels of the earth, or water. * Water, saturated with calcareous matter, adheres to vegetables and other substances, and thus by constant accretion, large masses of stone are formed. Witness the exuviæ of animals, and other things found in stone. In caverns and fissures, stalactitæ, laminæ of spar, lead ore, zinc ore, pyritæ, fluor, and other substances, crystallize in various forms, owing to water filtrating through the

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* Whitehurst.

the incumbent strata, and taking up in its passage a variety of mineral substances, and becoming thus saturated with metallic particles, which gradually exuding on the surface of the caverns and fissures in a quiescent state, the aqueous particles evaporate, and leave the mineral substances to unite, according to their affinities. Thus, in like manner, all beds of stone were originally in a state of fluidity.

In the union of bodies, a phænomenon always happens, which chymists call a dissolution. It is an attenuation, a division, a total dispersion of the solid body, brought into contact with the fluid body. Thus in the instance of chalk with the vitriolic acid. We here find their affinity to combination to be stronger than the natural texture of the solid; the aggregation, which united the molecules of the chalk, and which made it a solid body, being dispossessed of their property by the acid. * And hence, before two bodies can combine, one at least must be in a state of fluidity. But, it is not necessary, as the old axiom had it, that both should be fluid. "Corpera non agunt nisi sint soluta." One is generally sufficient.

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* Chimie de Fourcroy.

In the passing of a substance from a fluid into a solid state, it almost universally appears, (for there are exceptions) to have its parts arranged in a symmetrical order. Thus we see that most minerals; saline combinations, whether obtained by solution or sublimation; and metals, if suffered to *cool slowly*, have their peculiar forms, though in some more evident and distinguished than in others. This property called crystallization, is by some distinguished into two kinds: the one made in a menstruum, as salt crystallizes in water; and the other by mere cooling, as when water freezes alone. But, it long was a question whether stones, particularly precious stones, rock crystals and flints, were crystallized from a state of solution in water, or of fusion by fire. Many were of the latter opinion, though pure vitrifiable earth cannot be brought into fusion by the most powerful heat of our furnaces. "Yet," says Dr. Eason, "as a black flint has been melted without addition by the concentrated rays of the sun, it is probable there are, or have been degrees of heat in nature sufficient to produce the same effect. Moreover, it is probable that the immense masses of fires, which seem to be the cause of earthquakes and burning mountains, are sufficiently strong to bring into fusion the purest kind of vitrifiable earth. And as the stones above mentioned are known to be compounds, they must be more fusible than the vitrifiable earth simply: besides, in addition to that earth which makes their basis, they contain metallic calces, on which their colours depend, and a particular matter, determining the figure into which they crystallize."

But, all this admitted, there still remains an insurmountable difficulty. Flints are known, as I formerly instanced to you, to have unequivocal marine bodies in their very centers, and to lose in a very moderate degree of fire, both their transparency and their cohesion, as those stones do which have crystallized from water: rock crystal has sometimes a drop of water, and even vegetable and animal matters in their natural state, inclosed in its substance. The diamond is combustible, or totally to be consumed by the action of fire, without entering into fusion. These stones, therefore, could not have been produced by violence of fire; and the crystal pits in the Alps, afford satisfactory evidence that this kind of stone is a crystallization from water.

But, let us come a little closer to the question. Crystals are bodies, which though destitute of organic structure, yet externally resemble geometrical figures.* As a great variety of forms may be produced by the spathaceous particles accumulated in different ways, it is probable, that the difference crystals have in their consistency, surfaces, angles, and sides, is owing to variety in their mechanical elements. But, here a question may properly be started; whether the most minute molecules, and as it were the staminæ, be naturally possessed of a determinate angular figure, or whether they first acquire it during crystallization? This I cannot anwser. Experiment however seems to prove, that whether they have, or whether they have not, this determination in the molecules, they have, at one moment or other, a determinate angular figure. The watery particles concreting, exert a double tendency; by one of which, they are formed into spiculæ; by the other, these spiculæ are ranged in such a manner with respect to one another, as to form angles of 60 degrees: and hence the varieties observed in the particles of snow may be easily explained. We have, therefore, only to suppose, the particles which are employed in crystallization, to be endowed with a tendency to form spiculæ; and these spiculæ with a tendency to arrange themselves at equal angles of inclination, and we shall then have both the pyramids and the triangles, composed of them: as the angles of inclination vary, the triangles and pyramids will also vary; and hence the different forms of crystals will be produced. Upon any other supposition, than that of the existence of the mechanical elements under determinate and peculiar figures, it would likewise be impossible perhaps to assign a cause, which should arrange different substances, under different angles, and yet preserve these angles always constant in the same substance. Powdered resin, which must doubtless consist of particles of great variety of forms, when sprinkled on an electrophorus, is, by the electric fluid, formed into stars like those of snow: from the external appearance indeed, on all occasions, is warrantably to be denied, a suspicion concerning the identity of the internal constitution.

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* Bergman.

The most common method of crystallizing, is by means of water, as it easily takes up saline matters, and upon being sufficiently diminished by evaporation, yields them again in a concrete state; nay, until lately it had been thought, that without this vehicle, no crystals could be obtained. And yet it is asked, is water porous? Does it absorb into its pores, and without being in the least augmented in bulk, these very saline particles? The question, I confess, is difficult, however affirmatively it may have been determined by philosophers. The passage of light through it, indeed, and other phænomena, indicate the existence of vacuities in it. Yet, it is not readily to be explained, however solution be carried on, how even the smallest quantity of salt can be dissolved in the largest quantity of water, without increasing its magnitude. But, it is not only when actually dissolved in water, that crystals require determinate forms, but, it is also most probably the case, when they are only sufficiently attenuated and mixed with it; for substances not soluble in water, will yet remain suspended in it; and such substances doubtless possessing attraction, and also the necessary degrees of mobility, there seems to be no reason why they should not form crystals. And it appears highly probable, in reality, that many of the earths which occur in the mineral kingdom, symmetrical and of a regular form, have coalesced in this way. Crystals may frequently be obtained by fusion and slow cooling; glass, if melted, and slowly cooled, forms beautiful crystals. Scoriæ, taken from furnaces where iron has been fused, have been found of a regular prismatic figure. In large metallic masses, such especially as are difficult of fusion, the lower particles are generally so much pressed by the weight of the superior, that they shew no signs of crystallization, although on the upper surface of gold, silver, iron, and others, beautiful crystals are formed.

This property of crystallizing seems to belong to every solid body, provided its particles be so subtilely divided and suspended, either in the dry or in the humid way, that while they are again concreting, they may be at liberty to obey their mutual attraction. Nor when we say this, let it be thought extraordinary, that we should refer the congelation of water to an operation of this sort. Let it be considered, that it is by the means of the matter of heat, that water is fluid, and that when this matter of heat is diminished to a certain degree, it crystallizes, and becomes ice. Congelation, and crystallization, appear to be one and the same thing.

Some celebrated chymists, considering that many salts affect an angular form, and frequently one of a constant and permanent kind, have supposed this property to belong exclusively to salts; and when they have met with any bodies similarly figured, have attributed this figure to a salt, which they have fancied to be concealed in that body. But, this has been erroneous; as from experiment it has been found, that a very great number of crystals are either totally destitute of any thing saline, or else possess it in such small quantity, that no trials hitherto made, have been able to discover the least sensible traces of it. Gems, granites, schoerls, mica, and other earthy bodies, are frequently found figured, though analysis can discover nothing saline. The same is true of gold, silver, and the other native metals; as also of lead, tin, bismuth, and zinc united with mercury, of which all put on regular forms according to the quantity of the mercury.

In order however that the form of a crystal may be regular, three circumstances, it is said, are required; time, a sufficient space, and repose. Time causes the superabundant fluid to be slowly dissipated, and brings the integral parts nearer to each other by insensible gradation, and without any sudden shock. Their integral parts, therefore, unite according to their constant laws, and form a regular crystal. Space, or sufficient room, is likewise a condition necessary for obtaining regular crystallization. If nature be restrained in her operations, the product of her labour will exhibit symptoms of this state of constraint. A state of repose is likewise necessary in the fluid, to obtain any regular form. Uninterrupted agitation opposes all symmetrical arrangement; and in this case, the crystallization obtained will be confused and indeterminate. To saline substances, the water of crystallization is necessary; and crystallization is always said to begin at the surface of the liquid, or on the sides of that by which it is contained, merely because those parts are the first which suffer refrigoration. *

But, to obtain bodies under the form of crystals, a previous solution is not always necessary. A simple mechanical division is sufficient. Solution does not change the nature of bodies, but simply procures an extreme state of division; so that the disunited principles approaching each other very gradually, and without starts, can adopt themselves to each other, by following the invariable laws of their gravity and affinity. Now a division purely mechanical, produces the same effect, and places the principles in the same disposition. We ought not, therefore, to be

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* Linnæus.

be surprized, if most salts, such as gypsum, when dispersed in the earth, should assume regular forms, without any previous solution; neither ought we to think it strange, if the imperceptible fragments of quartz, spar, &c. when carried along, and prodigiously divided by the action of the waters, should be deposited in the form of regular crystals.*

The gems I have mentioned, have frequently also been ranked among saline bodies. But, in so doing, naturalists have regarded nothing but their figure. They have likewise been ranked among vitrescible stones. Those who class them so, besides various negative criteria of lesser moment, maintain, they have a glossy appearance, and that in fusion with fixed alkali, they run into a pellucid glass. The former of these assertions is not correct; the latter, indeed, refers to a quality more essential. Hardness is, in general, but a very vague mark, as it often depends upon the degree of exsiccation, the substance still remaining the same, as appears sufficiently in soft clay, when well burned. What some call vitrescent earths, others denominate siliceous; but, names change not the nature of things,

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* Chaptal's Chymistry.

things, those being the best, which are best adapted to it.

Gems, all consist of the same principles: argillaceous earths form the greatest part; then the siliceous, next the calcareous; and least of all the iron or ferrugenous. The two first ingredients vary extremely: they exceed all other bodies in hardness. What a prodigious degree of exsiccation, if exsiccaion is in truth to be admitted, is requisite to occasion such a degree of hardness! The heat of the temperate zone is supposed insufficient for this purpose, and the more constant and intense heat of the tropical climate absolutely requisite. Condensation is the necessary consequence of this hardness; hence the gems are more ponderous than the earthy crystals. But, on this head, I must confess I have some degree of hesitation. Exsiccation, we must indisputably allow to be necessary. But, as the rays of the sun penetrate only an inconsiderable way into the earth, can we, with strict philosophical precision, conclude, that exsiccation proceeds from the action of the external heat? The depth at which gems in general are found, is greatly out of the reach of the solar influence. Should we not then look for the operation of some other cause? I own the implicit adoption of the opinion, is beyond the reach of my faith. But, it is the celebrated Bergman who advances it; and he is too high in reputation, to be hastily deemed erroneous. We shall presently see what is to be said against so extraordinary a theory.

To the siliceous class, we may, without reserve, refer quartz and mountain crystal; porphyries, properly so called, and jaspers, but more ambiguously petro-silices and felt spar; as also zeolites, schoerls, and lastly, garnets, which are, as it were, intermediate between those and the gems, which are to be entirely excluded from siliceous earth, as not only by their nature, but by the proportion of their primary principles, they challenge a place among the clays. Most of the ambiguous stones abound in siliceous earths, and contain, besides portions of calcareous and argillaceous earths, certain portions of the silex also.

But, before we proceed on this subject, it may not be amiss to enquire into those elementary particles, of which these gems, crystals, &c. are said to be compounded. *Earths* are commonly understood to be tasteless, inodorous, dry, brittle, uninflammable substances, which are incapable of being metallized, and are scarcely soluble in water. They are, in their simple state, that white, friable substance, which remains of a bone, after all the other principles are burnt out of it; and will endure the utmost violence of fire, without being consumed or vitrified. The five simple earths are, the calcareous, the ponderous, the magnesian or muriatic, the argillaceous, and the siliceous. And all stones and earths, hitherto examined, are found to consist of these, either singly or mixed; or chymically united with each other in various proportions, together with saline, inflammable, and metallic substances. For in the earth they are seldom or ever found perfectly pure. The calcareous pure, constitutes a lime; the ponderous pure, is also in a state of lime, and perfectly resembles it in taste; the magnesian and argillaceous may likewise be called absorbent earths, as they are combinable with all acids; the siliceous alone is a crystalline, quartzy, or vitrifiable earth, as it is that of which glass is usually formed, and unites with no other than the sparry acid. *

All earths may be divided into simple and compound. Simple, as these five unalterable kinds,

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* Kirwan.

kinds, which constitute five sorts or genera; under which all terrene compounds may be ranged. Compound, as those that are combined or mixed in proportion, either with each other, or with a saline, inflammable, or metallic principle, yet not in sufficient proportion, to require them to be arranged under such foreign principles. Thus, gypsum is a compound earth, consisting of a calcareous earth, and a saline principle. But to say a few words concerning their more peculiar characteristics: argillaceous earth is distinguishable from the extreme subtilty and fineness of its integrant parts, which render it smooth to the touch, and slowly separable from water when diffused through it; also from a certain viscidity and ductility, which proceed from its power of retaining water: and of these properties magnesia also participates, though in a lesser degree. Siliceous earths, on the contrary, are characterized by roughness, hardness, sharpness to the touch, and a total want of flexibility, and adherence to each other, when minutely divided, and a ready separation from water: of these properties, calcareous and ponderous earths participate, though in a lesser degree. The earth alone, however, which can be looked upon as the menstruum of other earths, is the calcareous; for according to the important discovery of M. d'Arcet, they are all rendered fusible, by a proper proportion of this earth, though infusible of themselves.*

There is another earth on which chymists had long differed in opinion, namely, the earth of alum, one of the most valuable materials in the arts; the soul of the art of dying, and the mordant to all colours. At length the celebrated Margraaf demonstrated, that all clay upon the surface of the earth consisted invariably of two principles; one of which forms the genuine earth of alum, and is perfectly different from calcareous, gypseous, or metallic earths, and from magnesia. The tenacious and plastic quality of clay when moistened, its cracking when dried, and finally, the flinty hardness which it acquires in the fire, are all owing to the earth of alum. Its siliceous particles being such, as not to be capable of being either softened or hardened. Buffon, indeed, considered clay as flint minutely divided; and, on the contrary, flint, as clay very much condensed. But, he was in an error. There is certainly a portion of clay, though extremely small, which is always found even in quartz. But, the siliceous earth dissolved in fixed alkali, cannot, by means of the vitriolic acid, form alum. Moreover, when put to the test of experiment, the hypothesis falls to the ground; for pure clay is converted into alum by vitriolic acid; and the siliceous earth is not so much as dissolved by that menstruum. Common clay, to say no more of it, is a mixture of argill and siliceous earths, in which the latter mostly predominates.* All clays, however, which contain a mixture of calcareous or muriatic earth, or gypsum, or fluor, or felt spar, or iron, are more or less fusible.

In some way or other, however, all the substances hitherto examined in nature, have evidently appeared to be compounded of one or more of these elementary principles. As to the gems: the fossils so called, may be ranked thus: crystal, agate, jasper, emerald in form of pebble or crystal, carnelian, sarda, or sardius, all name sof the same stone; onyx, an undetermined transparent gem; sardonyx, a semi-transparent gem, which partakes of the flesh colour of the sardius, and of the zoned or tabulated form of the onyx; the topaz, called by the ancients chrysolite; the sapphire, the ruby, the carbuncle, which is a species of ruby, the beryl, which is a finer sort of crystal of the columnar form, the jacint or hyacinth, the

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* Kirwan.

the amethyst, the garnet, and diamond, or adamant, which excels every body in nature in two respects—first, in hardness, secondly in refracting light.

But, we must for the present leave these more precious and rare productions, and confine our enquiries to other crystallizations, which are abundant, and more evident to our senses. *Quartz*, as we have already seen, are of the siliceous genus, and in general contain a slight mixture of other earths. The most obvious distinction among them, arises from their transparency or opacity. Crystal is of the purest kind. Bergman has formed perfect crystals, by dissolving siliceous earth in the sparry acid, and suffering it to crystallize slowly. It is probable that nature forms them in a long course of time, from a solution or diffusion of this earth in pure water, or water that holds a little argill or calcareous earth, which probably enables it to take up more of the siliceous earth than it otherwise could.

Pure *mica* is colourless; but, either from a less intimate combination, or from a mixture of some superfluous ingredient, principally iron, it is found of different colours. Smooth, but not greasy to the touch, which distinguishes it from talc. Its texture, lamellar or scaly, and its appearance, sometimes splendidly metallic.* The slate or *schistus:* under this name are a great variety of stones; the *argillaceous grit*, free-stone, or sand-stone, is so called, because it may be cut easily in all directions. The *horn stone*, has besides a partial solubility, though without effervescence, in acids, a hardness never sufficient to strike fire with steel. It is frequently mixed with pyritæ; and De Saussure says, he is "firmly persuaded it is, when in a state of fusion, the first matter of lavas and basaltæ." *Common flint*, silex, or pebble, is found of all colours. It is composed of crystal debased with earth, and is commonly covered with an opaque white crust, which seems of the same nature, but more imperfectly combined. Flint is always semi-transparent in thin pieces; its hardness is various, though it always gives fire with steel; its texture is solid, whereas that of quartz is loose; it breaks with smooth surfaces, one of which is convex, the other concave; it is never found crystallized, but rather, in separate irregular nodules, scattered through other strata, and plentifully in England, in beds of chalk. It has seldom any fissures, with which quartz abound.

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* Kirwan.

Felt spar, or petuntze, is generally opaque, and is found of all colours; sometimes crystallized in rhombic, cubic, or parallelipedal forms, and often without any regular form: its texture close but lamellar, and breaks like spar. It never constitutes veins or strata, but is either found in loose masses, at most two inches long, or mixed with sand or clay, or embodied in other stones, as granites. *Schoerl* has a sparry or semi-vitrified appearance. It is always crystallized in some polygon form; its texture obscurely sparry: it is of all colours. The tourmaline is a variety of the schoerl. *Pudding-stone*, *breccias*, stones which consist of a siliceous ground or cement, (commonly petro-silex, jasper, or siliceous grit) in which pebbles of silex or agate are interspersed: if these be round or oval, they are called pudding-stones, if angular breccias. Of the coarser sorts, mill-stones are often made.

Granite has been supposed by naturalists, to be composed of grains of sand or gravel cemented together, and hence probably it derived its name. In granite, however, it is impossible to discover any cement, such as is observable in pudding-stone, breccias, and grit. All its parts appear integral, and seem so well adapted to each other, that one might say, they were petrified together, during the time, they were still flexible and tender. They indisputably were all formed in the same element and by the same cause, the principle of which was crystallization.[*] "J'ai vu dans le Lyonnois," says De Saussure, "dans l'Auvergne, dans le Gévaudan, dans le vosges, des lieus entieres de pays, dont le terrein n'etoit autre chose qu'un sable grossier, produit par la décomposition du granite, qui forme la base de ces mêmes provinces. Cela ne se voit que très-rarement dans les Alpes; les granites de ces hautes montagnes ont plus de solidité."

The granite consists of distinct masses of certain crystallizations, firmly compacted together; their proportion and size are extremely variable, as well as their colour. In the finer granites, the quartz is transparent, in others generally white or grey, violet, or brown; the felt spar white, yellow, red, green, or black. It is generally the most copious ingredient. The mica is also grey, brown, yellow, green, red, violet, or black, and is commonly least copious. The schoerl is generally black, and abounds in the granites that contain it. Hence the colour of the granite chiefly depends on the felt spar or schoerl. The red granites consist commonly of white quartz, red felt spar, and grey mica: The grey, of white quartz, grey or violet felt spar, and black mica. The black commonly contains schoerl instead of felt spar; the green, greenish quartz. If granite be exposed to a blow-pipe, its different concretions separate from each other.

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[*] De Saussure.

As to the *stalactitæ*, which are found suspended from vaults and caverns, they are formed by the oozing of water which is charged with calcareous particles, and which gradually evaporating, leaves the particles behind. But, this deposition can scarcely be called a crystallization, as the calcareous particles do not appear to have been dissolved, nor even very minutely divided, though this sometimes happens; whereas transparent spars appear to have been formed from a solution in water, by means of the aerial acid. *Calcareous incrustations* are generally found on the branches and roots of trees, and sometimes on stones of different kinds, and consist chiefly of calcareous earth, mixed with a small portion of siliceous and volatile alkali, together with some vegetable parts.

But, let us still enter more analytically into the composition of these solid substances of nature. There exists, as we have seen, a class of beings, which is composed of hard molecules, inodorous, not soluble in water, not malleable, and not inflammable. These primitive earths, combined among themselves, or blended with saline, inflammable, or metallic principles, form what is commonly called earth; and when indurated into masses, form what is commonly called *stone*, while in small quantities; and *rock*, when in large quantities. Many stones are opaque; many are transparent. Many are supposed naturally round in form; and many have been accidentally rounded by trituration in the waters: for, thus, though pieces of rocks and of other stones, as you will observe in beds of rivers, have been rounded by trituration in a fluid, it yet has been supposed that many, such as chalcedonies, agates, and flints, may have been originally round in their external formation.

The mineral kingdom has been usually divided into four classes: *earths* and *stones*, *salts*, *inflammable substances*, and *metallic substances*. Of the simple earths we have already spoken in a general way. Their peculiar characters are: *calcareous*, when perfectly pure and free from all combination, constitutes *lime*. It has a hot, burning taste, acts powerfully on animal substances,

stances, and when in lumps, heats with a moderate quantity of water. In the temperature of 60 degrees, it requires about six hundred and eighty times its weight of water to dissolve it; its taste is then pungent, urinous, yet sweetish. It is combinable with all acids, and in particular, easily soluble in the nitrous or marine, but with difficulty crystallizes with them, as it forms deliquescent salts, and is, in great measure, precipitable from them by the vitriolic, to which it preferably unites, forming gypsum or selenites. When in vessels, on which it cannot act, it is infusible *per se*, that is singly, in a heat that would melt iron. *Ponderous earth*, or *barytes*, when pure, is also in a state of lime, which it perfectly resembles in taste; but it requires nine hundred times its weight of water to dissolve it, in the temperature of 60 degrees. It is combinable with acids. It decomposes tartar vitriolate, an effect which no other earth can produce. And it is precipitable from the nitrous and marine acids, by the Prussian alkali, a property which also distinguishes it from all other earths. In the dry way, it acts, and is acted upon nearly as calcareous earth. *Magnesia*, or *muriatic earth*, requires about seven thousand six hundred and ninety-two times its weight of water, to dissolve it in the common temperature of the air. It is combinable with acids. Exposed to the strongest heat, it will neither burn to lime, nor melt *per se*; but loses much of its weight, partly by evaporation, and partly by the loss of a certain proportion of water, which it naturally retains. *Argillaceous earth*, or earth of alum, is exceedingly diffusible, but scarcely more soluble in water than pure magnesia. It is combinable with acids. The strongest heat barely hardens it, but, does not give it the qualities of lime, nor melt it, while single, or acompanied only with magnesia, or siliceous earth; but mixed with calcareous, it runs into fusion very readily. *Siliceous earth* is less soluble in water, than any other; yet, in the common temperature of the atmosphere, ten thousand parts of water may contain one of this earth; and in very high degrees of heat, much exceeding that at which water usually boils, it seems soluble in a much greater proportion. It combines with no acid hitherto known, except the sparry, which, either in a liquid or an aerial state, but particularly in the latter, is capable of holding much of it in solution. It is infusible *per se*, in the strongest heat; neither do argillaceous, or magnesian earths, promote its fusion; the effect of calcareous earth is somewhat more doubtful.*

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* Kirwan.

The calcareous, ponderous, magnesian, and argillaceous earths, being combinable with all acids, may be properly called *absorbent* earths, in contradiction to the siliceous, which unites only to the sparry acid. Of these earths, however, are composed the following stones: The *chalcedony*, in one hundred parts, has eighty-four parts of siliceous earth, and sixteen parts of argillaceous earth. The *opal* has a direct affinity with the chalcedonies; and the *oculus mundi*, which has the property of becoming transparent in water, is nothing but an opaque, decomposed opale.* *Jasper* is siliceous earth, blended with one-third of its weight of argillaceous earth, and one-sixth of its weight of the calx of iron; it hardens in the fire without melting.† *Petro-silex*, or *chert*, is siliceous earth, intimately mixed with from one-fourth to one-third of its weight of argill, and one-fifteenth to one-twelfth of its weight of calcareous.‡ *Silex*, or common flint, is siliceous earth, intimately mixed and partly combined with argillaceous and calcareous earths. In one hundred parts eighty are siliceous, eighteen argillaceous, and two calcareous.§ Flints, are infusible *per se*, in the strongest fire, but generally become white and brittle by reiterated calcination, which seems to indicate that they all contain a little water. The petro-silex differs but little from flint in external appearance, only it is duller and less transparent. It runs in veins through rocks, and hence its name. It whitens, and decrepitates like silex; but is generally more fusible, for it commonly melts *per se*.*

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* Bergman. † Kirwan. ‡ Kirwan. § Weigleb.

Quartz is various in its colour, figure, and texture. That of the colour of water, is called rock crystal. When crystallized in hexagonal pyramids, it is called mountain crystal; when in other forms, amorphous. The stones of this species are, in general, the purest of the siliceous genus, though most of them contain a slight mixture of other earths. The purest and most transparent of these crystals form the false diamond, called Bristol, or Kerry-stone, diamond d'Alençon, &c. In one hundred parts, ninety-three are siliceous, six argillaceous, and one calcareous.† *Agate* is a substance analogous to quartz, with this difference, that its molecules are less pure, and less homogene. It is a fine flint, mixed with various proportions of other earths, and iron. Of this substance there are great varieties. It is mostly found in small pieces covered with a crust, and often running in veins through rocks, as petro-silex. Agates that

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* Kirwan.

† Bergman.

that present arborisations, are called mochoes. *Felt spar* is a siliceous and argillaceous earth, mixed with magnesia, and terra ponderosa. It is of various colours. It has almost always a lamellar texture. It is sometimes of an undetermined form. It is generally found crystallized. It is harder than fluors, but not so hard as quartz. In one hundred parts of the white, sixty-seven are siliceous, fourteen argillaceous, eleven ponderous, and eight magnesia. It melts *per se*, more quickly and perfectly than fluors, into a whitish glass. Felt spar is undoubtedly the stone, the Saxons use in their porcelain manufactories. * *Jade* is a siliceous earth, blended with magnesia. It is found in scattered masses like pebbles, semi-transparent, of a greasy look, and exceeding hard. It is scarcely soluble in acids, at least without particular management, and is infusible in fire. † *Lapis lazuli* is a siliceous earth, intimately mixed with blue martial fluor, and a small proportion of gypsum. The colour of this stone is a beautiful opaque blue, and is generally sprinkled with yellow, bright pyritaceous specks or streaks. In a strong fire it melts *per se* into a whitish glass. ‡ *Zeolite*, in one hundred parts, has fifty of siliceous earth, twenty of argillaceous, and twenty-two of water, § and it is called so, on account of its forming a jelly with acids.

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* Kirwan. † De Saussure. ‡ Kirwan. § Pelletier.

Garnet, when not overloaded with iron, is transparent; though, from the intensity of its colour, which is a blueish or yellowish red, its transparency is often obscure. It is generally crystallized in polygon forms, but it is frequently amorphous. Its texture is granular. In one hundred parts, forty-eight, are siliceous, thirty argillaceous, twelve calcareous, and ten parts iron.* It is often found in small grains, embodied in stones of the commonest kind. *Schoerl*, in one hundred parts, has forty-eight siliceous, forty argillaceous, five calcareous, one magnesia, and one iron.† *Tourmaline* of Ceylon, in one hundred parts, has thirty-nine argillaceous, thirty-seven siliceous, fifteen calcareous, and nine iron.‡ *Ruby*, which is commonly found crystallized in an octohedral, is in texture foliated, and of extreme hardness. In fire, it is invitriable *per se*, and does not yield even to the focal rays of a burning glass: but, a flame excited by dephlogisticated air, directed by a blow pipe, readily melts it. It does not lose its colour in a heat that would melt iron.§ In one hundred parts, forty are argillaceous, thirty-

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* Achard. † Bergman. ‡ Ibid. § Kirwan.

nine siliceous, nine calcareous, and ten iron. *Hyacinth* is of a reddish yellow colour, generally crystallized in a prismatic form. In one hundred parts, forty are argillaceous, twenty-five siliceous, twenty calcareous, and thirteen of iron.* *Topaz* is of a gold colour, its texture foliaceous. In one hundred parts, forty-six are argillaceous, thirty-nine siliceous, eight calcareous, and six iron.† *Sapphire* is blue, its texture foliaceous. In one hundred parts, fifty-eight are siliceous, thirty-five argillaceous, five calcareous, and two iron.‡ *Emerald* is sometimes found in round flat pieces, but mostly crystallized in hexagonal prisms. In one hundred parts, sixty are argillaceous, twenty-four siliceous, eight calcareous, and six iron. *Chrysolite*, or *beryl*, is of a light yellowish green; melts *per se*; and is softer than crystal. *Aqua marine* is of a blueish green.§

Diamond is generally crystallized in octohedral crystals, but is sometimes found in round masses: its texture is lamellar. In a heat somewhat greater than that in which silver melts, diamond is entirely volatilized and consumed; it even produces a slight flame, and diminishes common air, just as phlogistic substances do, and leaves a soot, so that the extraordinary conjecture of Sir Isaac Newton, of its being an inflammable substance coagulated, is fully confirmed. The diamond cannot be arranged under any of the classes of earths, as it contains no earth. Its constituent principles are not known.* *Slate*, schistus durus, has, in one hundred parts, forty-six siliceous, twenty-six argillaceous, eight magnesia, four calcareous, and fourteen iron. There are many varieties. It is very brittle, and of a lamellar texture. *Pyritaceous schistus*, schistus aluminaris of *Wallerius*, is an argillaceous earth mixed with a siliceous earth, and pyritæ, a little calcareous earth, and magnesia. *Bituminous schistus*, is an argill mixed with silex, and a certain proportion of mineral oil or bitumen.† *Mica* has in one hundred parts, thirty-eight siliceous, twenty-eight argillaceous, twenty magnesia, and fourteen of the white calx of iron. This substance is white, yellow, green, red, brown, black, and lamellar or scaly; and the lamellæ, or scales, are slightly flexible, and often elastic. These scales are sometimes parallel to each other, sometimes interwoven, sometimes wavy or undulated, and sometimes they represent filaments. It is of no determined shape, and is crystallized. *Steatites* has, in one hundred parts, eighty siliceous

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* **Bergman.** † **Ibid.** ‡ **Ibid.** § **Kirwan.**

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* Kirwan.

† Bergman.

ceous, seventeen magnesia, two argillaceous, and nearly one of iron, in a semi-phlogisticated state.* *Soap rock*, or lapis olaris, is of a yellow colour, and sometimes whitish, but rarely black. It is somewhat harder than steatites, and probably the portion of argill is somewhat greater; but, in other respects it perfectly resembles it. The black contains a mineral oil.† *Serpentine*, lapis nephriticus, in one hundred parts, has forty-one siliceous, thirty-three magnesia, ten argillaceous, twelve water, and three of iron. ‡ In colour, and composition, it is variable. Its texture is either indistinct, obscurely laminar, or fibrous. It is harder than soap rock. *Fibrous asbestos*, alumen plumosum, is mild magnesia, combined with silex, calcareous earth, and a small proportion of argill, and iron. ‖ It is generally of a green colour, and consists of filaments, either parallel to, or interwoven with each other. *Amianthus*, resembles the fibrous asbestos. It is composed of long parallel fibres, flexible, and soft to the touch. In one hundred parts, it has sixty-four of silex, eighteen of magnesia, seven of calcareous earth, six of barytæ, three of argill, and two of iron. § *Limestone* is sometimes of a lamellar, and sometimes of a granular texture. Its colour is various. It is calcareous, but contains some small proportions of argill, quartz, and iron. The aerial acid is in greater quantities than in spars. *Marble* is a calcareous substance of variety of colours.—That of Carara is the purest we are acquainted with; it is of a granular texture, and sparkling in its fracture like sugar.* *Gypsum, alabaster, selenites,* have each a calcareous base. They are of various colours, and are in texture lamellar, granular, or fibrous. Gypsum, in one hundred parts, has forty-six of vitriolic acid, thirty-two calcareous, and twenty-two of water.† *Ponderous spar,* is a terra ponderosa, combined with the aerial acid, and aerated baroselenites. It is compact or lamellar, undetermined in figure, or crystallized. *Baroselenites* is of a white, grey, or yellowish white colour, and some reddish; sometimes not harder than chalk, but mostly very compact, and of a stony hardness. Its texture is lamellar or fibrous; its shape various. It decrepitates in fire, but does not burn to plaster of Paris, as gypsum does. It often forms the stony matter of petrifaction. In one hundred parts, are eighty-four of earth, thirteen of the most concentrated acid, and three of water.‡ *Hepatic stone,* or leberstein of the Germans, has, in one

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* Bergman. † Kirwan. ‡ Bayen. ‖ Bergman.

§ Bergman.

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* Kirwan. † Macquer. ‡ Bergman.

one hundred parts, thirty-three baroselenites, thirty-three silex, twenty-two alum, seven gypsum, and five petroleum. The texture of this stone is always scaly.* *Sands* are composed of hard, disunited particles, which appear to have originally appertained to stones or rocks. They are found of various sizes, sometimes almost impalpable. *Porphyry* has a compact, siliceous ground, generally jasper, chert, schoerl or lava; and contains either felt spar, quartz, mica, serpentine, or other species of stone, in a crystalline form.§

And here, I think, are specimens enough of the composition of stones. As I have said before, however, when in a small volume, they are called stones; and when in a large volume, they are called rocks; and these rocks, again, are divided into two classes: *primitive*, or those which appear to have been formed of substances, which were all in a state of fluidity at the same moment, and which are called *granite*; *secondary*, or those formed of fragments, and cemented by a lapidific gluten, and which are called *breccias*, as well as those formed of sands, and cemented by a similar gluten, which are called *grit*, free-stone, or sand-stone. Of the primitive

* Bergman.

§ De Saussure.

mitive rocks, as they are not found to contain either animal, or vegetable remains, it has been conjectured, their crystallization took place, anterior to organized nature. Pallas looks upon them as the principle ingredient in the structure of the globe; and the fact is undeniable, that they have been found at the most profound depths, the industry of man has been able to fathom, as well as to be the most elevated parts of the highest mountains of the earth. But of this, more in the sequel.

LETTER XXX.

IT was long held as an established doctrine, that as all colours, concentrated and blended into one, would yield the pure effulgence which the sun darts upon the univerſe, so would all minerals and metals brought into a mass, produce the first parent of them all, Mercury. But this at length, as if by general consent, has been exploded; and among a variety of other reasons, from the paucity of the instances where, in any mine, excepting its own, the living Mercury is to be traced. To feign the elementary mercurial principle, as the basis of metals, was indeed chimerical. It is much more reasonable to suppose, that all metals and minerals are but different modifications of earths. For why should that be supposed in all metals, which cannot be extracted from any of them, and is producible only from the red ponderous earth of cinnabar? Nature does not present us with a multitude of principles, but with an endless variety, arising from the different combinations of a few. The arbitrary ideas, however, relative to Mercury, are now no longer heard of. Philosophers now know, that, in its common state, it is to be considered as a metal in fusion; (for Pallas says, it has been several times congealed in Siberia, by the natural cold) and since in its solid state, it is nearly as malleable as lead, it by no means ought to be ranked in any other class, than that of a distinct, and perfect metal.

Minerals, in their strictest signification, denote only such substances, as are found in mines, such as metals, semi-metals, sulphur, and salts; but in a more extensive sense, they denote all fossils, that do not belong either to the vegetable or animal kingdoms; and consequently, stones and earths, all of which are comprehended under the denomination of the mineral kingdom. The knowledge of the formation of minerals, is still a desideratum in philosophy. Some men have conceived, that they take their origin from an eager and acid vapour, or from a vitriol and a nitre strongly fermented, and blended with a salt and a subtile earth; and that the more the earth is subtilized, the purer is the production. But this is far from being ascertained. Metals, says Bergman, never occur in a perfectly pure state. Gold is contaminated more or less with silver, copper or iron; silver with copper and arsenic; copper with iron; nickel with cobalt, and so on. It is highly probable, continues he, that all the metals are only different acids, coagulated by a large quantity of phlogiston, although the connexion of those principles is so close, that we are hitherto ignorant of the means of separating them. Metallic calces always contain more or less phlogiston, and most of them ærial acid. But, Bergman is said here to have been mistaken. For of the metals, and semi-metals, gold, silver, copper, mercury, bismuth, and arsenic, are often found pure; iron, rarely; and tin, as rarely. The existence of native lead, indeed, is still a problem; and the same may be said of the regulus of antimony, of zinc, and of cobalt. But, notwithstanding the metals are not all found in the virgin state, it yet is curious, that each perfect metal should have a correspondent semi-metal, with which it has a more or less marked analogy. Thus, we shall find that antimony has an affinity with tin; that zinc has an affinity with iron; that arsenic has an affinity with copper; that cobalt has an affinity with silver; that bismuth has an affinity with lead. And, finally, that mercury has an affinity with gold, and in so intimate a manner, that it has not been found possible to separate them.* Is the white brittle metal, that results from this union, at any great distance from platina? †

It has been invariably observed, indeed, that all the metallic substances which can in any manner be decomposed, are in their first principles, formed of a metallic earth and phlogiston; a remarkable resemblance even has been supposed between metals and charcoal, both having an intimate union of phlogiston, with an earthy base; and this has induced the generality of chymists to think, that the perfect metals are also composed of the like materials, so well combined, that the utmost efforts of art are not able to separate them. This, however, is not altogether satisfactory; for no such thing could ever be produced, as the calces of any of the perfect metals, except when they were mixed in a small quantity, with certain extraneous substances, such as glass, &c.‡ Nor is it every kind of earth, which combined with a certain quantity of phlogiston, can form a metal; nor can the calx of one metal, by any one known method, be made to form another metal. The calx of iron can form nothing but iron; the calx of lead, will make only lead, and so of the rest. It may in truth be possible in nature, to make a metal out of something else besides a metallic earth. But, that which is most remarkable relative to metals is, that while in a state of dissolving, if they are kept undisturbed, they turn out a perfect metallic fluid; but, if on the contrary, they are shook somewhat too rudely, they resolve into a totally different substance.

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* Brandt. † Romè de l'Isle. ‡ Cavallo.

All the metals, excepting platina and gold, are dissolvable by aqua fortis. The quantity of air discharged from metals, is supposed to be the cement or principle, which unites all the parts together in a native state. The fumes that arise from them during their dissolution, are deadly posion; and when condensed, have every appearance of arsenic. These properties, that is, their proneness to give way and separate, by the agency of one universal menstruum; their abundance of air, for much even is to be extracted from gold; together with the mephitic vapour which they send off, prove to the conviction of many philosophers, that they must be necessarily homogeneous. This, however, is as little ascertained as their formation.

tion. The only thing which appears to be certain is, that they are by no means primary productions of Nature, but that they take their form in the gradual succession of time; and that fissures and caverns of rocks are the laboratories, where such operations are carried on. It is an universal, and an invariably true observation, that minerals are most generally contained in the fissures of lime-stone strata (although granite sometimes, as in Scotland, presents them) and between their laminæ, and not in the solid substance of the stone. It is not, however, equally true, that mines and mineral fissures, are only to be found in mountains and hilly countries: they are often found in the beds of rivers, and in veins upon the shores of the ocean, where the ocean is the boundary of extensive plains. This situation, indeed, is not so favourable for discovery, the superficies of the strata of plains being commonly covered by earth, sand, clay and gravel.

We are intirely ignorant, as I have already said, of the essential principles of metals. We do not know, whether each metal hath an appropriate earth, or whether the same earth, differently modified, be employed in all. In general, not only minerals of all kinds, but sulphurs, salts, and even stones, have been said to have been the produce of certain acid, aqueous, phlogistic and earthy combinations; and hence, they have been classed as salts, stones, sulphurs, or inflammable substances, and metals or metallic substances. The epithet salt, has been confined to certain bodies, soluble in water, and endued with a savor, more or less pungent. Stones have been looked upon as substances, insoluble in water, and generally infusible by themselves; metals and minerals, as specifically heavier than stones, and requiring only a certain degree of heat to put them in fusion. But these classifications are by no means rigidly exact, for there are salts, which are indissoluble in water; while there are stones, such as the gypsum, which are soluble in water; and a crystalization, a shoerl, which, as a metal, is capable of fusion by heat.*

The most specific character of the mineral kingdom is *crystalization,* though it has formally been denied by some of the most able mineralogists. In the animal, and vegetable kingdoms, the species are endued with organs essential to their developement by intussusception, and these organs are contained in the germ of each individual.

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* Romè de l'Isle.

vidual. On the contrary, in the mineral kingdom, salts, stones, inflammable substances, and minerals, have nothing which can warrant the supposition of germs, or of any internal organization. The whole of this kingdom results from the attraction and combination of elementary molecules, whose tendency to union increases as the molecules are found more simple, and more attenuated. Nor, though foreign molecules may sometimes find their way into the general substance of any one particular, are we to suppose a general, or even a very frequent confusion. Some are undoubtedly found mixed, but a perfect homogeneity is the usual characteristic. The properties of any one homogeneous substance, are never altered by the presence of any other crystaline substance. Each preserves its character distinct. I mean here, such as have relation to exterior form, to relative or specific weight, to hardness, and to transparency or opacity; for instance, the rock crystal: this fossil often contains metals, and other bodies; silver, copper, mica, shoerl, amianthus, felt-spar, marcasites, &c. It is found in all parts of the earth, and yet in no part is it found different from another, or unaccompanied by its determined and appropriate angles.

This elective attraction manifests itself, from the simple geode, to the enormous granite masses which form the most stupendous mountains of the earth. Each has, first, a particular crystalization, with certain determined angles. Secondly, a specific gravity. Thirdly, a specific degree of induration. Thus, we are not to stop at the mere crystaline formation, for that is general; though it is at the same time demonstrable, that each species has an invariable geometrical arrangement of its parts: and hence, we may safely conclude, that the mineral kingdom, that assemblage of brute, inorganic bodies, unprovided with the internal configuration necessary to life, to growth, and to reproduction, has yet distinct families and species, as clearly discriminated, and as uniformerly continued by the invariable laws of combination, as animals and vegetables are by the invariable laws of fecundation. In this, indeed, as in the other kingdoms of nature, there are frequently deviations, that is, there is distinct and positive crystalization, indeterminate crystalization, and confused crystalization.*

The ancients looked upon rock crystal as a congealed water, which by length of time, had become more indurated than ordinary ice. Pliny says this in express terms, and that it was found no where but in those regions where snow and winter take up their eternal abode, as in the caverns in the Alps, or other lofty mountains. That crystal is generally found in high mountains, is certain, and the reason is clear, because the most elevated mountains are granite, one of the chief ingredients of which, is rock crystal, or quartz. Certain modern chymists, have in some degree also, adopted the same idea, particularly those who have admitted the *transmutation of water into earth*. Morveau has even been led to conjecture, that from its intire evaporation by heat, the diamond, the hardest crystal in nature, can be nothing but pure coagulated water. The phænomena of crystalization, are in truth, wonderful. Lapides crescunt; vegetabilia crescunt, & vivunt; animalia crescunt, vivunt, & sentiunt. *

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* Romè de l'Isle.

Crystalization takes place, and can only do so, when the molecules are in a state of liquifaction, and are separated one from the other by the interposition of a fluid, such as the fluid of water, of fire, of mercury, aeriform fluids,

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* Linnæus.

and in short, all fluids capable of holding the crystaline matter in suspension. By evaporating, by cooling, or by substracting from the fluid, the molecules approach towards each other, come into contact, and at length firmly unite. The presence of air, together with the agency of heat or of cold, are those commonly necessary to crystalization. But, towards ascertaining the legitimacy of a crystaline substance, it is not essential that it should have decided points, and be angularly arranged. Agates, chalcedonies and flints, are all of a crystaline substance: the spherical, or globular masses called geodes, are also crystaline, though they are, as it were, externally uncrystalized; and although the internal parts of each are clearly and evidently marked. Neither is an absolute degree of exsiccation in any wise necessary. The same substances have always the same properties. Were it not so, the crystal of the East would be harder than the crystal of the West; the gem of the Equator would be harder than the gem of the Tropic. Even superior tenacity and cohesion of parts do not give superior gravity. The diamond is the hardest of all stones, and yet it is not so heavy as the ruby or saphire. The ponderous spar is the heaviest of all spars, and yet, is one of the most brittle. Gold is the densest of all metals, and yet has not the hardness of iron: neither can lead, which is the softest, be said to be the lightest. The superior degree of hardness then, is not in proportion to density, as was supposed by Bergman. These two qualities, as well as the crystaline form, being the immediate product of attraction, must exist in crystalized substances, from the very moment of their combination; and this, whatever may be the situation in which they are found, and whatever may be the temperature of the climate in which they are formed.*

There is a considerable difficulty, it must be confessed, in the arrangement of crystaline bodies; for if we find causes of uncertainty in regard to organized beings, how many more must we find in regard to unorganized beings. In the one, where specific forms are determined by specific germs, we yet are often puzzled to mark the limits of each species. How much more so must this be the case in fixing the limits of a kingdom, where the sole force of cohesion unites their elements, whatever be their nature, and in whatever proportion, or by whatever accident they have been assembled. In fact, however,

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* Romè de l'Isle,

however, the phænomena of the salt, the stone, the inflammable substance, or the metal, are not in themselves more surprizing than the phænomena of figure and flavor invariably given to vegetables and to fruits. The internal process of crystalization is not, indeed, thoroughly understood. But is it more a mystery than the generation of animals, or the vegetation of plants? In reality, we can artificially form crystaline bodies, even, it is said, the crystal of the rock.* We can even augment their volume. But the best microscope that was ever formed, cannot manifest to our senses, the manner in which the augmentation is accomplished. The elementary particles of matter, are undiscoverable by us. The smallest atom, that even with the aid of magnifying glasses, we can barely discern, is yet a compound, and not a single being. Nevertheless, it may be asserted concerning crystals, that they are, generally speaking, to be considered as *neutral salts*, soluble either in water, fire, acids, alkalis, air, or various other menstrua, unknown to us, in nature. As to their mechanism, whether brought about in the wet, or in the dry way, whether by nature, or by art, it seems universally to be the same, the combination of an acid, or some substance performing

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* Achard.

forming the functions of an acid, with one or more bodies, calculated to saturate and to neutralize the acid principle.*

There are seventeen metallic substances now known, namely, gold, platina, silver, copper, iron, lead, tin, mercury, zinc, regulus of antimony, regulus of arsenic, bismuth, cobalt, nickel, regulus of manganese, siderites, and regulus of molybdena. Of these, gold, silver, platina and mercury, are reckoned perfect or noble metals; because when calcined, they recover their phlogiston without the addition of any phlogistic substance.† The metallic substances, properly so called, all agree in the common definition of metal, which is, that it is a hard, shining mineral body; fusible by heat; concretable by cold; malleable or ductile under the hammer, and the heaviest of all bodies.

Gold, is only dissolvable in aqua regia. Silver, discovers more of a vegetable and arborescent configuration than any other metal, whether in its native, or in its dissolved state: it is dissolvable by aqua fortis. The chief distinguishing property of copper, is in sound, it being the most sonorous of all metals. Iron is

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* Romè de l'Isle. † Kirwan.

the hardest of all metals; and until lately, was supposed the only body in nature susceptible of the magnetic power: it dissolves in aqua fortis with a rapidity of effervescence beyond any other metal; and is corroded by the acid in the air, and becomes rusty very readily: is rarely found pure, but generally in ore; and may be extracted by the loadstone from plants. Tin is the lightest of all metals; not at all sonorous; has the least fixity in fire of any metal; it intimately mixes with every other metal, and makes them all brittle but iron. Lead, the heaviest of all metals excepting platina, gold and mercury, is the softest of all metals, has the least elasticity, and is the least fixed in fire. Mercury, when in a solid body, is as hard as lead, whiter than tin, and is both ductile and malleable. Brass, steel, pewter, &c. are compounds. But the metal superior to all, is the platina, which is heavier than gold itself.

Metallic substances have an absolute opacity. Stones have some sort of transparency; but the smallest bit of metal is to the full as opaque as the largest. Hence they are so eligible to the reflection of the rays of the sun. And it is from the want of this opacity, that quicksilver is so useful in giving glass the power of reflecting images. White metallic substances reflect the rays, and are more brilliant than those that are coloured. Metals have a specific weight greater than other minerals. They have a property from ductility of extension. Thus lead and tin can be beat out; gold, copper, and iron can be drawn out.* Chymists, call those substances metals, which unite ductility with opacity; and with weight, brilliancy. And those which have the appearance, but not the ductility of metals, they call semi-metals. Those are called perfect, which undergo the least sensible alteration. Those imperfect, which lose their metallic properties in the process.

Metals exist in the earth, in three different states. 1. As virgin or native, that is, in possession of all their properties; as gold is generally found, and silver often as is copper, mercury, bismuth and arsenic: rarely iron; more rarely lead, zinc, the regulus or metallic part of antimony; but rarest of all, tin, or a singular species of arsenical ore, called cobalt. 2. As an earth or lime, that is to say, not having any metallic appearance. Copper is often found as a green or blue lime; sometimes regularly crystalized; iron in the state of rust, and white or coloured spar, sometimes crystalized. Lead in that of crystalized lime, and of red, green, or white spar; tin in the same variations; zinc in the state of calamine; cobalt in red flowers; and arsenic in white lime. 3. Constitutes that which is most common, where, as in mines, the metals are combined with certain matters, which deprive them of their metallic properties, which they do not regain until they are separated. Sulphur is the substance that most generally unites with metals. The veins of metals are accompanied by stony substances, by quartz and spars, which seem to have been formed at the same time. They in general form two beds; one for the metal to lie upon, and the other as its cover. They do not blend, however, so intimately as the sulphur.

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* Chymie de Fourcroy.

All metallic substances seem to owe their formation to water. The greatest part are to be found crystalized. Some preserve the organization of a vegetable or animal. The fire, indeed, has been supposed to have formed some.[*] Mountains have their substances more immediately for our observation, and particularly those which run in chains. The plants which grow on these mountains, are observed to be arid; the trees crooked and ugly; the snow to melt almost as soon as it falls. In fine, the very gravel is frequently seen to exhibit metallic colours. But as I said before, the mercurial substance, from its amazing weight, its habitual fluidity, its extreme volatility, and the singular alterations it is capable of manifesting, is the most surprizing of all these metallic bodies. Besides the old ideas concerning it, it has been regarded as a metallic water, a water which does not wet one's hands, "Aqua non madefaciens manus." It is true, it does not wet one's hands, or many other bodies which are to be wet by water, by oil, and other liquors. But this phænomenon results merely from its having no affinity with these bodies. For as I have already remarked, when it is in contact with certain substances, with which it can unite, as gold, silver, tin, &c. then it intimately applies itself, and wets them in such a manner, that they cannot be dried unless by evaporation caused by fire. A phosphoric light, is sometimes to be observed to proceed from mercury, and yet at the same time, a hand plunged into it, is sensible of great cold. A thermometer plunged into it, proves it to be of the temperature of the atmosphere, and no colder.

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[*] Fourcroy.

It is found sometimes in large masses. It is generally combined with sulphur, and then it forms what is called cinnabar. The corrosive sublimate is an artifical preparation; as is the amalgam, which is merely an incorporation of mercury with some other metal: this latter, however, can be rendered so powerful, as that metals by amalgamation shall be confounded and entirely concealed within each other.

Besides the properties of other metals, iron, which next to tin is the lightest of all metals, has three in a great degree its own. One, is the property of being attracted by the magnet, and the power of becoming itself a magnet, by resting in a position south and north, or even by standing perpendicularly. The second, is the property of inflaming, for steel filings, small steel wire, burn by the least approach of ignited bodies; and producing sparks of fire, when struck against a flint, for the sparks are nothing else put particles of steel separated by the hard flint, and set on fire by the violence of the stroke. The third, is its being the only metallic substance that is found in plants and animals, and serves to give colour to a part of their humours. For it gives in reality, all that truly astonishing variety of colours, which are comprehended between the blue and the deepest red. It is even probable, that organized bodies, form within themselves this metal, for plants reared in pure water contain iron, as may be proved from their cinders, whence iron is to be extracted. It is very abundant. It is found in almost all coloured stones, bitumens, and mines of other metals. It is not uncommon to see organized matters, such as wood, leaves, barks of trees, and shells, changed into iron. And what is more striking, no organized matter is ever found changed into any other metal, which shews its affinity to those substances. There is scarce any art, in which iron is not employed. M. Macquer calls it the soul of the arts. It is the only metal that has nothing pernicious in it to organized bodies, vegetable or animal.

In decomposition, as you will readily conceive, consists the great art of chymistry, and this proceeds from a knowledge of affinities. Let us suppose, for instance, two bodies which strongly adhere to each other, as an acid and, a metal. Present to them a third substance, which has a stronger affinity with the acid, suppose an alkali; the result will be, the alkali having a superior tendency to unite with the acid, than the acid had with the metal, the bodies will be separated, and the alkali will take the acid to itself; and the operation of this is called precipitation. It is proved also, in opposition to Stahl and others, that two or more bodies united, form a matter, the properties of which are new, and very different from these, which each of those bodies possessed before their junction. Marine acid and mercury, given separately, and in doses of a few grains in a glass of water, are not capable of injuring the animal economy; while the same dose of corrosive sublimate, formed by the combination of these two substances, and administered in the same manner, is a most violent poison. The oil of vitriol and the oil of tartar, make a solid. The solids of neutral salts combined with ice, make a fluid. But all substances have not an equal tendency to blend. Iron and mercury can never be intimately united.

We have already noticed the difference between the noble and the ignoble metals, and that they were all to be dissolved by aqua fortis, excepting gold. This king of metals, to speak with the ancients, is only to be dissolved by a mixture of the nitrous and the marine acids, though neither of them, when separate, has any effect upon it. It is directly attracted by dephlophlogisticated muriatic acid, by aqua regia, and nitrous acid; but the other acids, being deficient in power to carry off the necessary quantity of phlogiston, do not take it up, unless it has been precipitated from some one or other of these three.

But there is a substance, which, from its very deleterious qualities, it is highly necessary you should be made acquainted with; I mean *litharge*, that metallic substance formed out of the spume, foam, or froth of lead. It is found in furnaces where silver is refined, and hence, its name λιθαργυρος, that is, λιθος a stone, and αργυρος silver. The litharge sold in the shops, is produced from copper works. Litharge is properly, lead vitrified, either alone, or with a mixture of copper. But lead is dangerous in a variety of instances, especially if employed in domestic vessels and utensils. Fountains and basons of it, in which water is kept, are often so noxious, as materially to hurt that element. The vapour and the powder of it are pernicious. But the *saccharum saturni*, sugar of lead, or ceruse, as it is commonly called, is of all, perhaps, the most pernicious. It is this property, unfortunately, which lead has of acquiring a sweet taste by a solution in acid, that has rendered it so serviceable to those venders of wine, who respecting their own profit more than the lives of their fellow creatures, have not scrupled to attempt to recover wines which have turned sour, by putting into them large quantities of ceruse, or litharge,* a palpable poison. This offence is in Germany puniſhable with death. It is on account of the poisonous quality of litharge, that the use of white paint on the skin is found so destructive to the constitution.

As I have above said, however, of all metallic substances, iron is the most common. It is to be met with in the three kingdoms of nature. It is not only one of the principles which gives colour to plants, as well as to animals, but, when dissolved by the phosphoric acid, it always assumes a brilliant red colout itself. The ruby, the blood, and even wine, are each severally coloured by the combination of iron with the phosphoric acid. By variety in its combination, it always affords variety in tints.† It was long a received opinion, also, as I have above remarked, that metals were not inhabitants of the primordial mountains. But, besides the familiar instance of Scotland,—at Scharfenberg, in Saxony, veins of silver are found in granite.‡ Among the Pyrenees, the richest veins of lead are found in the same rock.* Nature, therefore, is not so limited as has been supposed, in those mineral gifts which give to agriculture and arts their best instruments; to manufactures their best materials; and to commerce and society, the medium by which they are supported, and the chain by which they are linked.

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* Bishop Watson. † Sage. ‡ Charpentier.

And now I think we have looked at metallic substances in their most striking features. During our inquiries into the nature and properties of the permanently elastic fluids, we adverted to the lime, or the residuum of metals, acquiring a considerable degree of weight. We then saw, that it was heavier than the metal itself, previous to calcination. Astonishing assuredly it is, that a body shall augment in weight, by losing one of its constituent parts. But the fact seems to be as M. Macquer argues, that metals cannot lose their phlogiston and calcine, but in proportion as the pure air of the atmosphere is precipitated and united to their substances; and that they are not reduced until the phlogiston, aided by heat, disengages the pure air. Chymists have looked upon rust as the lime of metals.

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* Dietrick.

The wild idea of making the most perfect of all these metals, gold, existed among the Egyptians and the Greeks, and was found among the Arabs, when the English, French, Germans, and Italians, went to the Holy Land, during the Crusades. From the 11th to the 16th centuries, it was carried to the most extravagant excess: will you believe it, that within these six centuries, more than six thousand volumes have been published on the Elements and Practice of Chymistry; or the greatest part of them, more properly speaking, on the best means of artificially making gold? The contrariety of ideas on the subject of mineralogy, even from the year 1730, hath been astonishing. You cannot but have heard of Bromel, Linnæus, Cramer, Wallerius, Cronstedt, Woltersdorff, Gellert, Cartheuser, Justi, Lehman, Vogel, Stahl, Bergman, Scheele, Baumer, Valmont de Bomare, Buffon, Bucquet, D'Aubenton, Hill, Sage, De Saussure, Kirwan, Romè de l'Isle, Monnet, and multitudes of others.

At the same time you are not to forget, that gold was formerly used very plentifully in medicine. This remedy was particularly much in fashion in the 15th century. The goodness has at all times been proportioned, you know, to the dearness of the drug. Bernard de Palissy exclaimed strongly against the Apothecaries of his time, who demanded ducat gold from the sick to put into their medicines, under the pretence, that the purer the gold, the more speedy would be the restoration of the health of the patient. Alchymy was therefore defined, *ars sine arte, cujus principium est mentiri, medium laborare, tertium mendicare*. But there was a class of Alchymists, whose genius, probity, and conduct, we have reason to venerate. They enriched chymistry with the best products we are acquainted with. Nor are we to treat disrespectfully, the study of that mineral kingdom whence the wants and conveniences of man are so amply supplied. And now I will relieve you from the subject, with just remarking, that gold is chiefly found in larger and smaller grains, blended with the composition of the rock; and this is the reason why so much gold dust, and grains, are found in the beds of rivers: and that lead, copper, and other ores, are found generally in the composition or fissures of the solid body of the rock. Allow me also just to mention to you, two or three metallic phænomena. For instance, a plate of copper, immersed in a solution of silver diluted in water, precipitates the metal. The silver adheres at the moment of precipitation to the surface of the copper, where it forms a kind of moss. In proportion as the silver is precipitated, the water assumes a blue tinge; which proves that the copper is dissolved in the nitric acid, in the room of the silver. When the whole of the silver is disengaged, and the water is poured off, the silver is dried, and fused in crucibles, to be cast into ingots. This silver, however, almost always retains a small quantity of the copper. Silver is likewise precipitated by mercury, and as the arrangement gives the form of a vegetation, it is called *arbor dianæ*. There is also a powder, lately discovered, to be produced from silver, more astonishingly fulminating than even fulminating gold itself.* Gold is precipitated from its solution by several metals, such as lead, iron, silver, copper, bismuth, mercury, zinc and tin. This last precipitates it instantly in the form of a powder. Gold may likewise be precipitated from its solution by æther. This liquor seizes the gold in a moment, and sometimes instantly revivifies it. The gold is sometimes seen to form a stratum at the surface of the liquor, and the two fluids no longer to contain a particle. Copper ore, sometimes forms sulphate of copper in its decomposition. This salt is dissolved in water, and forms springs more or less loaded with it, from which the copper may be obtained by cementation. Old iron is thrown into the water, the copper is precipitated, and the iron takes its place; not that the iron, according to vulgar belief, is transmuted into copper. In this manner it is obtained in Hungary, in England, and in Ireland. The skeletons of animals are sometimes found in copper mines, penetrated with that metal. We read even of a human carcase found in the great copper mine at Fahlun, in Sweden, which had remained there forty years, with the flesh and bones entire, without corruption, and without emitting any smell.*

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* Berthollet.

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* Acta Literaria Suec; anno 1772.

LETTER XXXI.

THE science of fossils comprehends, as you have seen, the knowledge of all the various bodies which are dug from the subterraneous parts of the earth; whether they be such as were naturally formed there, or originally belonged to the animal and vegetable kingdoms, and were deposited by some change in the course of nature. The Heathens adopted the most whimsical notions of fossils. They could not account for them. Even Pliny and Theophrastus believed (or seemed to believe), that stones bred, and brought forth young ones.* Nor is the mist even yet dispelled, for as I have already remarked, it has been a question with philosophers, whether stones do not grow in the earth? There certainly, however, seems to be no clear evidence to prove, that an integral pebble buried in the earth, is larger now than it was a thousand years ago. The contrary, indeed, is plain, from its retaining those marks of attrition which pebbles get by rolling against each other in the water. Thus much, however, does appear, that there is in some parts of the earth a petrifying fluid, with which a broken stone will be reconsolidated like a broken limb; and heterogeneous matters, as shells and pebbles, will be found coagulated into a strong mass.

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* Philosophy of the Elements.

But let us cast our eyes again on the great subject on which we were engaged, and from which we have strayed, merely from the desire of running through the whole system of crystalization. Again let us plunge into the body of the waters. The continents on which we stand, were, as we have formerly said, the bottom of the sea. The surface which we now behold, received its configuration from the currents, the movements, and the inexplicable accidents it met with in the ocean. In the internal parts of the earth, as far as the excavations made by natural causes or by the industry of man, have given scope for observation, we have had striking marks exhibited, of the immense changes that have been produced by the chymical action of bodies on each other, during a course of ages preceding all human record. The loftiest mountains, which run in chains through the great continents, and are composed chiefly of *granite*, were found, previously to the existence of animals and vegetables upon the present earth. The same also, it is presumed, applies to mountains of lime stone, or marble of a granular texture, and is grounded on the consideration, that the remains of organized substances are never found in them.* Calcareous stones, says De Saussure, are universally allowed to be productions of the sea. To prove this, the vestiges of marine animals may be demanded. But the sea does not in every part of it produce shells. Moreover, there are oftentimes local causes, such as an abundance of the acid principle, which may alter and hinder petrification, nay even preservation. I have observed, continues this philosopher, and with great astonishment, in the argillaceous hills of Tuscany, and above all, in the environs of Sienna, for instance, near Monte Chiaro, that the hills contiguous to each other, are many of them so filled with fossil shells, that the earth has absolutely been white; but, on the contrary, that the others have been without the smallest trace of a shell. In the high mountains of the Alps, the slates, and calcareous stones, which appear to have been formed immediately *after* the primitive rocks, seldom or never contain vestiges of marine animals; whereas those in the flat country, or in inconsiderable mountains, always abound with them.

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* Nicholson's Philosophy.

The calcareous substances of which we are here speaking, are indisputably formed in the bowels of the deep. The sea is the laboratory whence shells and other marine matters are deduced, which are necessary for ſuch coacervations. But, what an astonishing difference between the soft consistency of some of these animals while living, and the hardness of the masses formed from them when dead! losing their organic form, for such we must suppose to be the process, they crumble and pass into a calcareous substance; then indurate, and in such a situation, furnish an occasion for conjecture concerning the antiquity of the earth. This proprety, of rendering animal substances calcareous, says Mr. Douglas, seems to be intirely undefined by any of our learned Naturalists. Must not the agent which has operated upon these substances, be in its effect similar to fire? By some chymists, this reduction has in truth been attributed to acids. An acid menstruum, indeed, continues he, has been lately discovered, which will dissolve the hardest bodies; and it is well known, that the decomposition of fluor spar, united with the vitriolic acid, greatly fermented with the aſſistance of fire, will, in paſsing through water, crystalize, and probably indurate animal bodies opposed to it. This chymical effect then may now perhaps be operating; and in the maſſes at the bottom of the ocean, be generating those phænomena which in future ages are to surprize, as much as their counterparts do at this moment. Nature has been at all times, and must continue to the end, *sibi semper similis.*

From this I acknowledge, it might be inferred, that marine animals were created prior to terrene animals, otherwise why are fossil shells, why are the echini, the entrochi, the glossopetra, and the relicks of other fishes, so universally found in the deepest as well as in the most elevated strata of the earth? But from such an inference, I must entirely and unequivocally withhold my assent. I cannot admit that marine animals were created prior to man, and all other beings. I will acknowledge it appears clear, even to demonstration, that those marine shells which are found fossil, were generated, lived, and died, in the very beds where they are found, and were not brought from distant regions by a flood or floods, as some have supposed;

posed; and consequently that such beds were originally the bottom of the sea. I will also confess, that shell fish increase prodigiously; insomuch, that it is not uncommon to take away a bed of shell fish several fathoms in extent, and yet there shall be as many the ensuing, as there were found there the former year. But, in a priority of existence, however it might free one from embarrassment in establishing a theory of the earth, I shall never be able to bring my mind to acquiesce. Probability, and reason, are too strongly against it.

The number of sea shells found in a fossil, or in a petrified state, is so amazing, that were it not for this very circumstance, we never should have had a proper idea of the surprizing quantities of those animals, to which the ocean gives birth: they appear in masses like mountains; in banks of 100, and 200 leagues in length; and from 50 to 60 feet thick.* Lime stone, marble, chalk, marle, &c. together with various others, owe their origin to shells. Nay more, I will venture to affirm, says Buffon, that shells are the medium employed by nature in the formation of almost all stones. Many fishes inhabit the deepest parts of the ocean, and are never thrown upon the coasts; these are termed *pelasgi.* Those thrown upon the coasts, are called *littorales.* The *cornu ammonis* probably belongs to the former: for these animals, the *cornua ammonis*, are no longer found in any of our seas. Shells are sometimes found more than 1000 feet below the surface; and on the top of the mountain called *Le haut de Veron*, which is elevated more than seven thousand feet above the level of the sea, fragments of petrified oysters have been found. Chalk, says Monnet, occupies a space of more than 600 miles in Picardy, Boullonais, Artois, French Flanders, and Soissonnais; and often a depth of more than 400 feet. Nor is it unworthy of remark, says he, that chalky countries are almost always lower and less mountainous than other countries; that their valleys are less profound, though they are larger and more spacious. A distinction of course ought to be made between positively chalky, and simply calcareous countries. Another remark, no less worthy of attending to, he further observes, is, that chalky and calcareous substances, almost always affect an horizontal direction, whereas Schistus affects an oblique, or a perpendicular direction.

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* Buffon.

How natural and satisfactory, therefore, is the conclusion of Mons. De Saussure, that it is more than probable, though at a considerable depth below the surface of the Lake of Geneva, that the calcareous beds of *Mount Jura* unite to those of *Saleve*, and the first chain of the Alps.

Elevations, consisting chiefly of clay, sand, or gravel, are called hills; those that consist chiefly of stone, are called mountains, as they are the chief repositories of minerals, and particularly of metallic ores. That the formation of these mountains preceded that of our present races of vegetables and animals, is justly inferred, as we have above noticed, from their containing no organic remains, either in the form of petrification or impression; from their bulk, extension and connexion, which seem too considerable to be ascribed to subsequent causes; and from their use and necessity for the production of rivers, without which, it is hard to suppose the world had existed at any period, since the creation of animals. Granites were formed by crystalization. * This operation probably took place when the various species of earths, already dissolved or diffused through the mighty mass of the waters, were disposed to coalesce; and among these, the siliceous must have been the first, as they are the least soluble:

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* Kirwan.

but as they have an affinity to other earths, with which they were mixed, some of these must also have united with them in various proportions, and thus have formed in distinct masses, the felt-spar, shoerl, and mica, which compose the granite.

Calcareous earth enters very sparingly into the composition of this stone; but it is found in shoerl, which is frequently a component part of granite. Quartz can never be supposed to be a product of fire, for in a very low heat, it bursts, cracks, and loses it transparency; and in the highest we can produce, it is infusible, so that in every essential point, it is totally unlike glass, to which some have compared it.* As granite contains earths of every genus, we may conclude, that all the simple earths are coeval with the creation. Their simplicity, however, may be only relative to the present state of our knowledge; for water itself, as we have seen, though it undoubtedly dates from the creation, is by late experiments said to be a compound: a miracle, to avail myself of an expression of Burnet, not less striking, the turning of air into water, than the turning of water into wine.

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* Kirwan.

Mountains, which consist of lime stone or marble of a granular or scaly texture, and not disposed in strata, seem also to have preceded the existence of our present animals; for no organic traces are found in them. Also those that consist of stones of the argillaceous genus, and of the compound species of the siliceous genus, seem to be primœval, as they contain no organic remains: these often consist of parallel strata of unequal thickness; and the lower are harder and less thick than the upper; whence, the lower seem to have been first formed, and the upper, later. They are the principal seat of metallic substances, whose ores run across the strata in all directions, hence they are by the French called *montagnes á filons.* Coal is never found in them. Alluvian mountains, as they are denominated, are evidently of posterior formation; as they contain petrifactions, and other vestiges of organic substances; and are always stratified.

Granite is considerably interesting, from the beautiful works of which it is the constituent matter; from its great age, and from the principal part it acts in the composition of the globe.* It is likewise greatly interesting, from the nature of its structure, and from the few lights we have in regard to its nature and formation. Of this species of rock, the matter of the most elevated mountains is composed, such as the central chain of the Alps, the Cordelliers, Imaüs, Caucasus, &c. It is never found seated on slate, or on calcareous stone. On the contrary, slate and calcareous stone are frequently found seated on granite. Hence granites carry the just title of *primitive mountains*; while those of slate and calcareous stone, are qualified with that of *secondary mountains*.

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* De Saussure.

In the structure of mountains, beds may be frequently seen, as in Mount Jura, which occupy, as it were, the centre, or very heart of the mountain, and which are perpendicular to the horizon; and this, in those of primitive as well as of secondary formation. On this subject, says De Saussure, I had long thought, that all beds ought to be horizontal; and that those which were not so, had been so placed by some revolution in the earth. But in consequence of having repeatedly remarked them, and that too in mountains of the most perfect preservation, which to all appearance, had never undergone any overthrow or disorder; and having found them always in a form and direction of the lead are found in the same rock.* Nature, therefore, is not so limited as has been supposed, in those mineral gifts which give to agriculture and arts their best instruments; to manufactures their best materials; and to commerce and society, the medium by which they are supported, and the chain by which they are linked.

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* Buffon.

How natural and satisfactory, therefore, is the conclusion of Mons. De Saussure, that it is more than probable, though at a considerable depth below the surface of the Lake of Geneva, that the calcareous beds of *Mount Jura* unite to those of *Saleve*, and the first chain of the Alps.

Elevations, consisting chiefly of clay, sand, or gravel, are called hills; those that consist chiefly of stone, are called mountains, as they are the chief repositories of minerals, and particularly of metallic ores. That the formation of these mountains preceded that of our present races of vegetables and animals, is justly inferred, as we have above noticed, from their containing no organic remains, either in the form of petrification or impression; from their bulk, extension and connexion, which seem too considerable to be ascribed to subsequent causes; and from their use and necessity for the production of rivers, without which, it is hard to suppose the world had existed at any period, since the creation of animals. Granites were formed by crystalization. * This operation probably took place when the various species of earths, already dissolved or diffused through the mighty mass of the waters, were disposed to coalesce; and among these, the siliceous must have been the first, as they are the least soluble:

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* Kirwan.

but as they have an affinity to other earths, with which they were mixed, some of these must also have united with them in various proportions, and thus have formed in distinct masses, the felt-spar, shoerl, and mica, which compose the granite.

Calcareous earth enters very sparingly into the composition of this stone; but it is found in shoerl, which is frequently a component part of granite. Quartz can never be supposed to be a product of fire, for in a very low heat, it bursts, cracks, and loses it transparency; and in the highest we can produce, it is infusible, so that in every essential point, it is totally unlike glass, to which some have compared it.* As granite contains earths of every genus, we may conclude, that all the simple earths are coeval with the creation. Their simplicity, however, may be only relative to the present state of our knowledge; for water itself, as we have seen, though it undoubtedly dates from the creation, is by late experiments said to be a compound: a miracle, to avail myself of an expression of Burnet, not less striking, the turning of air into water, than the turning of water into wine.

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* Kirwan.

Mountains, which consist of lime stone or marble of a granular or scaly texture, and not disposed in strata, seem also to have preceded the existence of our present animals; for no organic traces are found in them. Also those that consist of stones of the argillaceous genus, and of the compound species of the siliceous genus, seem to be primœval, as they contain no organic remains: these often consist of parallel strata of unequal thickness; and the lower are harder and less thick than the upper; whence, the lower seem to have been first formed, and the upper, later. They are the principal seat of metallic substances, whose ores run across the strata in all directions, hence they are by the French called *montagnes á filons*. Coal is never found in them. Alluvian mountains, as they are denominated, are evidently of posterior formation; as they contain petrifactions, and other vestiges of organic substances; and are always stratified.

Granite is considerably interesting, from the beautiful works of which it is the constituent matter; from its great age, and from the principal part it acts in the composition of the globe.* It is likewise greatly interesting, from the nature of its structure, and from the few lights we have in regard to its nature and formation. Of this species of rock, the matter of the most elevated mountains is composed, such as the central chain of the Alps, the Cordelliers, Imaüs, Caucasus, &c. It is never found seated on slate, or on calcareous stone. On the contrary, slate and calcareous stone are frequently found seated on granite. Hence granites carry the just title of *primitive mountains*; while those of slate and calcareous stone, are qualified with that of *secondary mountains*.

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* De Saussure.

In the structure of mountains, beds may be frequently seen, as in Mount Jura, which occupy, as it were, the centre, or very heart of the mountain, and which are perpendicular to the horizon; and this, in those of primitive as well as of secondary formation. On this subject, says De Saussure, I had long thought, that all beds ought to be horizontal; and that those which were not so, had been so placed by some revolution in the earth. But in consequence of having repeatedly remarked them, and that too in mountains of the most perfect preservation, which to all appearance, had never undergone any overthrow or disorder; and having found them always in a form and direction of the